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OF THE

SCIENTIFIC LABORATORIES

OF

DENISON UNIVERSITY

EDITED BY
FRANK CARNEY

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A GEOGRAPHIC INTERPRETATION OF CINCINNATI, OHIO[1]

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[1] Work done in an advanced course in Geography under the direction of Dr. Carney.

To the observer who stands upon the bluff at Eden Park, Cincinnati's "Garden of Eden," and looks down upon the bustling twentieth century life of the city below, it seems a far cry to the days when the Five Nations roamed these regions, and France, England and Spain contended for the supremacy of the great Northwest. Now there is a seemingly endless procession of railroad trains, electric cars, fast-speeding automobiles and vehicles of every description; smoke pours forth from thousands of smokestacks of large manufacturing establishments; packet-boats ply up and down the Ohio, and ponderous barges move slowly along with their immense cargoes of coal. Yet but little more than a century ago, Cincinnati was only a pioneer village, whose inhabitants lived their simple lives in daily terror of Indian raids.

What has brought about the transformation? From the pioneer days to the present time, geographic influences have played an important part in Cincinnati's industrial development. As men have responded to these influences, Cincinnati has grown into one of the nation's most famous manufacturing centers, a city whose industrial and commercial interests are enormous to a degree far exceeding the average of cities of its size.

Location of Cincinnati

General surroundings. The city of Cincinnati is situated in the extreme southwestern part of Ohio, in an amphitheatre about 12 miles in circumference, bisected by the Ohio River, which passes through it in a course from east to west. The river front available for Cincinnati's shipping is about 10 miles long, and the city has a fine public landing, an open area of ten acres, with

1000 feet front. The shore is paved from low-water mark, and furnished with floating wharves, which rise and fall with the river. Cincinnati is bounded on the south by the river, and on the north, east and west by hills, 300 to 400 feet high, which form the walls of an amphitheatre, with the business section of the city lying at their base, situated on a series of terraces.

Location central in the Ohio Valley. Cincinnati is central to the Ohio Valley. Pittsburg, where the Ohio River is formed by the junction of the Monongahela and the Allegheny, is 960 miles from the Mississippi River; the distance from Pittsburg to Cincinnati is 458 miles. Lake Erie is 500 miles from the sources of the Kanawha and the Tennessee; Cincinnati is about half-way between, and almost on the line. The principal tributaries of the Ohio are the Muskingum, Great Kanawha, Big Sandy, Scioto, Miami, Green, Kentucky, Wabash, Cumberland and Tennessee Rivers. About 210,000 square miles are drained by the Ohio and its tributaries, and Cincinnati holds the strategic position in this region.

Connections with the East. The city is connected by navigable rivers and by railroads with the ocean and with the interior river coast. Of the great railroad lines which cross the passes of the Appalachians, all except the direct lines of the New York Central pass through Cincinnati. The Norfolk and Western, the Chesapeake and Ohio, the Baltimore and Ohio, and the Pennsylvania connect Cincinnati with the East.

Geographical boundaries of Cincinnati. Geographically speaking, Cincinnati includes more than the limits of the city, since Cincinnati occupies only a part of the wide valley of a former mature river. The older portion of the city, nearest the river, is a depressed area, 300 feet below the general level of the country, somewhat semi-circular in shape, bounded as stated above. A smaller half-basin, similar in shape, is occupied by Covington and Newport, Ky., towns lying just across the river from Cincinnati, this half-basin being intersected by the Licking River and semi-circled by hills. In a very remote period, the Walnut Hills area, one of Cincinnati's eastern hilltop suburbs, was directly connected with the Kentucky highlands, lying east of Newport. The Price Hill area, a western hilltop suburb of Cincinnati, was connected with the south-lying hills of Kentucky. The Licking River then flowed northward toward Hamilton. These hills

were cut apart, and the course of the Ohio at Cincinnati today was brought about, as a result of later drainage adjustments.

Cincinnati, Covington and Newport commercially one city. From a geographical point of view, then, Cincinnati, Covington and Newport are all one, and they are so treated in this discussion. Commercially, also, Covington and Newport are suburbs of Cincinnati, though legally they are distinct municipalities. Separated from Cincinnati by the Ohio River only, over which stretch five bridges, and within twenty minutes' reach of the city's business center, the majority of these Kentucky citizens have their business interests in Cincinnati, are employed in her numerous industrial establishments, and are largely dependent on her for their prosperity. While these towns have a creditable number of manufacturing establishments, they make large use of Cincinnati's transportation facilities in shipping their products. Almost from the founding of Covington and Newport, their development has been closely associated with that of Cincinnati, and geographically these towns are "South Cincinnati," as they are sometimes called.

The Founding of Cincinnati

Symmes' Purchase. The founding of Cincinnati, or Losantiville, as it was originally called, was due primarily to the attraction of the Miami Valley's rich soil. Major Benjamin Stites, of Brownsville, Pa., passing through this region, was so impressed with its fertile fields, fine forests and beautiful streams, that he decided to found a permanent settlement in the neighborhood. In partnership with Judge John Cleves Symmes, of Trenton, N. J., Major Stites shortly obtained possession of 1,000,000 acres of this Miami country, bordering on the Ohio River.

Advantages of the Miami region. River valleys always attract settlers, and this Miami Valley is a peculiarly advantageous location. It is not far vertically from sea-level, the country in general is about 500 feet above sea-level, the surrounding hills about 200 to 300 feet higher. Furthermore, it is well watered. The Licking River joins the Ohio from the Kentucky side, just opposite Cincinnati, while at the time of the first settlement the Great and Little Miami, which drain this Miami country and are tributary to the Ohio, were bounded for many miles by land of unsurpassed fertility.

Grain grew abundantly in this region—wheat, rye, corn, buckwheat, barley, oats and hemp—tobacco was produced of a quality much superior to Virginia tobacco, while fruits of all kinds commonly found in a temperate zone were grown to advantage. Game was plentiful, and the rivers were well stocked with fish.

The rock formations of this region consist of alternating layers of blue clay-marl and blue or lead-colored fossiliferous limestone, bituminous shale and fine-grained sandstone, covered with black mold and amber loam, a combination which makes a very fertile soil. The wells and springs afforded a very pure limestone water, and the water of the Ohio does not contain a noticeable amount of mineral matter.

Three settlements. Three settlements were made on the Ohio at about the same time in 1788: one at Columbia, near the mouth of the Little Miami; one at North Bend, near the Great Miami; one at Losantiville, afterwards called Cincinnati, opposite the mouth of the Licking. At first the settlements at Columbia and North Bend grew more rapidly than the Losantiville settlement, this more rapid growth being due in considerable measure to the fact that temporary fortifications had been built at North Bend and Columbia, for protection against the Indians, while at Losantiville there was no military protection.

Building of Fort Washington. In the spring of 1789 there was a flood on the Ohio, and the fortifications at North Bend and Columbia, being situated on low ground, were submerged.[2] Major Doughty was sent out by the federal government to investigate conditions, and after studying the topography of the region, he decided upon Losantiville as the most available place for a permanent fortification, by reason of the river's high bank. Accordingly, Fort Washington was built at this point, this fort being sufficiently large to accommodate 1500 soldiers. After Fort Washington was completed, the settlers at North Bend and Columbia began to throng to Losantiville, which led Mr. King to remark, in his *History of Ohio*, that "whatever Cincinnati may have suffered since by floods, she doubtless owes her start to that of 1789."[3] In 1790 the name of the settlement was changed from Losantiville to Cincinnati by Judge Symmes, this name being authorized by Governor St. Clair.

[2] Rufus King, American Commonwealth Series, *Ohio*, 1891, p. 212.

[3] *Ibid.*, p. 213.

Influences in early growth. Judging from conditions today, the region about North Bend would be the proper location for a large city, since it is near the mouth of the Great Miami, which drains such a large fertile region to the north. But the influence of this recent stream, in reference to the Ohio, is secondary to that of the old stream valley above referred to. Cincinnati lies in the valley of the Old Licking, where the Licking, from the Kentucky side, joins the Ohio, which is of much later origin in this part of its course. A very few miles up the river the Little Miami empties into the Ohio. The valley of the Licking, and the turnpikes in Kentucky, led settlers easily from the Kentucky regions, which were becoming thickly settled at that time, while large numbers came later from the east by way of the Ohio.

Early Years of the Settlement

Indian depredations. During the first few years of the settlement, no attempt was made to establish any industries. Fear of the Indians kept the settlers together, and their efforts were confined almost exclusively to agriculture. The Peace of Greenville was concluded in 1794; fear of savage depredations thus being removed, industrial progress began.

Ferry and packet line established. In 1792 a ferry was established opposite the Licking, and legal rates were fixed by Governor St. Clair.[4] In 1794[5] a regular packet line was established to Pittsburg, while keels, flatboats and barges carried the farm products of the rich Miami country down the river to New Orleans, and in turn brought supplies from New Orleans to Cincinnati. A good road led down from Newport to Lexington, the center of Kentucky's rich farm region, and the farm products of Kentucky were brought to Newport, ferried over to Cincinnati, transferred to boats and carried down the Ohio to the Mississippi.

Cincinnati's Rapid Industrial Growth

Population and manufacturing statistics. Though population figures are not a sure index of a city's commercial standing, yet a very rapid increase in population is usually an indication of

[4] W. H. Venable, *Cincinnati and Hamilton County*, p. 65.

[5] Ohio Archeological and Historical Society Publications, vol. vi, 1900, p. 241.

industrial progress, hence Cincinnati's population statistics are of interest. Below are the figures from the beginning of the nineteenth century to the last census, 1910 (including Covington and Newport); also the manufacturing statistics from 1840 to the present time:

	Population	Manufactures		Population	Manufactures
1800	856		1860	187,561	$56,995,062
1810	2,953		1870	255,831	70,000,000
1820	9,642		1880	305,292	145,947,280
1830	26,289		1890	358,197	218,751,545
1840	48,364	$16,366,443	1900	397,141	169,498,035
1850	130,738	46,189,279	1910	448,012	206,288,000[6]

INDUSTRIAL GROWTH FROM 1800 TO 1850

Reasons for Cincinnati's rapid industrial growth. During the first half of the last century, Cincinnati grew more rapidly than any other city in this country. In addition to the general reasons for the prosperity of the Miami country, there were also special reasons why Cincinnati should become a manufacturing center. Raw materials for manufacturing were easily accessible. Clays for making brick and pottery were abundant in the lower part of the town, limestone was present in large quantities in the beds of the Licking and the Ohio, and the materials for glass making were at hand in great abundance. Wood was plentiful in the neighborhood, and coal was brought down the river at a very cheap rate. Iron ore from the Hanging Rock region was easily accessible. Moreover, Cincinnati had splendid harbor facilities. In 1815 the prediction was made by Dr. Drake[7] that Cincinnati was to be the future metropolis of Ohio, by reason of its location opposite the Licking, and its great expanse of shore, with no shoals or reefs to prevent the landing of boats.

Growth from 1800 to 1820. During the first twenty years of the nineteenth century, Cincinnati's population increased about thirteen-fold, and the city became known as, next to Pittsburg, the greatest place for manufactures and mechanical operations on the river.

Influence of transportation lines. This commercial progress was doubtless largely due to the fact that during this period steam-

[6] Approximate.

[7] Daniel Drake, *Picture of Cincinnati,* 1815, p. 231.

boats came into general use, thus greatly increasing the facilities for river transportation. Roads also played their part in this industrial development. In 1817 The Cincinnati and Hamilton Turnpike Company was incorporated, also The Cincinnati and Dayton Turnpike Company. At this time there were roads connecting Cincinnati with Detroit, Mich., Vincennes, Ind., New Orleans, La., Greenville, O., Louisville, Ky., Chillicothe, O., Williamsburg, Ky., and Pittsburg, Pa.

Demand for manufactures. Cincinnati was primarily impelled to become an industrial center by the growing demand for manufactured articles on the part of the farmers. The rich areas of the Miami region were becoming thickly settled, and the regions along Zane's Trace were rapidly developing; consequently the farmers needed various articles. It was an expensive and difficult task to transport manufactured articles across the Appalachian mountains. Accordingly, Cincinnati began to supply the home demand in different parts of Ohio and Indiana, since access to Cincinnati was easy by way of the Ohio and the roads mentioned above.

Growth during 1820 to 1840. This was a period of very rapid progress. The population increased five-fold; in twenty years Cincinnati grew from a town of about 10,000 inhabitants into a city, with a population as large as that of Springfield or Youngstown today. In those early days this was an unparalleled growth.

Influence of canals. In 1840 the value of Cincinnati's manufactures was $16,366,443.[8] This industrial progress was largely the result of the building of canals, connecting Cincinnati with the East. The Erie Canal was completed in 1825, joining Lake Erie and the ocean. In 1830 the Miami Canal, which was to connect Cincinnati and Toledo, reached Dayton;[9] in 1845 it reached the lake. Between 1830 and 1840 there were constructed also the Ohio Canal, connecting Lake Erie and Portsmouth, and the Whitewater, which connected Harrison and Cincinnati. These canals furnished an easy and reliable means of communication. At that time there were no railroads in the West. Rivers were the chief means of transportation, and Cincinnati exceeded all other Western cities in the number of her boats. Vessels ply-

[8] *Ohio Statistics,* 1880, p. 768.

[9] *The Ohio Gazeteer,* Columbus, 1839, p. 258.

ing between Cincinnati and New Orleans carried immense quantities of grain and other farm products down the river, and brought back supplies for the grocery trade. The canals filled in the gaps in the transportation system. When the Upper Ohio was not navigable, goods were brought from New York by the Hudson River to Buffalo, then by the lake and the Ohio Canal to Portsmouth and on down the river.

Highways. During this period several pikes were built. In 1840[10] fourteen macadamized roads proceeded directly from Cincinnati, connecting the city with all the important towns of Ohio. The Dayton and Springfield Road, by its connection with the National Road at Springfield, connected Cincinnati with Wheeling and Baltimore. Through Baltimore, Cincinnati had access to Virginia and the Carolinas. Thus, by means of the river, the roads and canals, Cincinnati had access to the north, east and south.

Public improvements. In the decade ending with 1840, extensive public improvements were made in the city. The shore of the river was paved from low-water mark, and floating wharves were built. A good system of street-lighting and a well-equipped city waterworks were installed.

Slaughtering and meat-packing center. Cincinnati was foremost in the slaughtering and meat-packing industry at this time, being known as "the pork shop of the Union." Sir Charles Lyell, a distinguished Englishman who visited Cincinnati about 1840, bestowed upon the rich merchants of the city the rather slighting title of "Pork Aristocracy."[11]

From 1840 to 1850. In the next decade, Cincinnati made the most phenomenal growth of any city in the country. Her population increased over 80,000, and the value of her manufacturing products increased almost three-fold.[12] In 1850 Cincinnati was the fifth city in the Union in population. Her manufacturing products, which at that time constituted more than one-half the business operations of the city, yielded a profit of $25,000,000 yearly, almost one-half the whole amount obtained. The manufactures at this time included almost every known variety of industry. Among the largest items were those of packing prod-

[10] Charles Cist, *Cincinnati in 1851*, 1851, p. 131.

[11] Sir Charles Lyell, *Travels in North America*, New York, 1845, vol. ii, p. 61.

[12] *Ohio Statistics*, 1880, p. 768.

ucts, alcohol and spirits, boots and shoes, clothing, foundry and engine shop products, and furniture.

Influence of transportation lines. The influence of the canals was greatest during this period. The railroad fever had seized the citizens of Ohio, but there were very few railroads in operation previous to 1850. A road was completed from Cincinnati to Springfield in 1846, and by 1848 through steam connection was made between Cincinnati and Sandusky.[13] Within the next decade several railroads were completed, but preceding 1850 canal shipping was the most important factor in Cincinnati's growth.

INDUSTRIAL GROWTH SINCE 1850

From 1850 to 1870. During the decade preceding the Civil War, Cincinnati's development was naturally retarded by war agitation, in common with other cities all over the country; her population increased about 57,000, but the value of her products increased less than $11,000,000. In the Civil War period, her population increased about 67,000, while the value of her products increased only about $14,000,000.

1870 to the present. Since 1870 Cincinnati's growth, both in population and manufactures, has been steady and consistent. From 1870 to 1880 her manufactures more than doubled, the influence of the Civil War having disappeared. In the next decade her manufactures increased satisfactorily. During the decade ending in 1900, the value of her manufactures decreased, due probably to the panic of the nineties; in the last decade the manufactures show a pleasing increase. Since 1850 the value of Cincinnati's manufacturing products has increased about four and a half-fold, while the gain in population has been almost three-fold.

Influence of the railroads. This progress has doubtless been largely due to the building of railroads. The day of the canals was over by 1850. In 1851 Cincinnati and Cleveland were connected by railroad; in 1852 a railroad was built from Cleveland to Pittsburg.[14] In 1853 the Baltimore and Ohio Railroad reached the Ohio valley; in 1857 a road was built, connecting Cincinnati with St. Louis. The year 1857 was also marked by the completion of the Ohio and Mississippi Railway, which connected Cin-

[13] Ohio Archeological and Historical Society Publications, vol. ix, 1901, p. 190.
[14] *Ibid.*, p. 190.

cinnati with five of the states along the southern seaboard. In 1859 the Louisville, Cincinnati and Lexington Railway (afterwards the Louisville and Nashville) was completed to Nashville. By 1870 Cincinnati was connected by railroad with Baltimore, Philadelphia, New York, Toledo, Chicago, St. Louis, Louisville, Lexington, and several important southern cities. Since that time railroads have been multiplied, and facilities for river transportation have been greatly increased; as a result, Cincinnati's manufacturing establishments have multiplied many-fold, and commerce has steadily grown.

The Cincinnati of Today

Population statistics. What place is held by the Cincinnati of today, in comparison with other large cities? According to population statistics (including Covington and Newport), Cincinnati is the tenth city in the United States, and second in Ohio, with a population of 448,012. Twenty years ago Cincinnati stood seventh, with a population of 358,197. According to population statistics, Cleveland, Ohio's leading city, ranks as the sixth city in the United States, with a population of 560,663. Twenty years ago Cleveland held tenth place, with a population of 261,353.

Manufactures. In regard to manufactures, however, Cincinnati is a close rival to Cleveland. In 1910 Cincinnati's manufactures (including Covington and Newport) amounted to $206,288,000. Cleveland's manufactures amounted to $271,961,000, having more than doubled in the last decade. But Cleveland's manufactures per capita amounted to $485; Cincinnati's per capita manufactures amounted to $464.

Cleveland has an advantageous location on the Great Lakes, which are the natural highway of the commerce of the Northwest. Furthermore, a great part of Cleveland's manufactures consists of steel and allied products. In 1890 $30,000,000 of Cleveland's $113,000,000 of manufactures were steel products. In 1900 her steel manufactures had increased to $51,000,000, over one-third of her products. In 1905, which is the latest date for which detailed census reports are available, $72,000,000 of Cleveland's $172,000,000 of manufactures consisted of steel products. The supply of ore in the Lake Superior region is not inexhaustible.

When this supply is used up, Cleveland's chief industry will be destroyed, and her rapid progress will cease, unless she finds some way to adjust herself to the changed conditions.

Cincinnati's manufactures are general. Her chief industrial products rank as follows: Distilled and malt liquors, clothing, slaughtering and meat-packing products, foundry and machine shop products, boots and shoes, printing and publishing, carriages and wagons, tobacco, cigars and cigarettes, and furniture. Cincinnati produces more soap than any other city in the country, and is foremost in the manufacture of vehicles. Ohio, in 1900, held third place in the production of liquors in this country, and 76 per cent of the distilled liquors produced in the state come from Cincinnati. Over one-half the clothing manufactured in Ohio also comes from this city.

For many years Cincinnati was the packing center of the country, but as the center of corn-growing moved westward, she yielded her preëminence to Chicago, though her packing interests are still very large.

In the manufacture of pottery, Cincinnati's position is eminent. Rookwood Pottery, which was founded about twenty-five years ago by a prominent woman of Cincinnati, has now become world-famous; its products go to all the countries of Europe, and are acknowledged to be unique. This pottery is made largely of native clays, though some clays are imported.

The Cincinnati of the Future

What of the future? Is it probable that Cincinnati will ever regain her place as the leading city of Ohio in population? What advantages has Cincinnati over other cities, which should enable her to make more rapid progress along industrial lines?

Cincinnati's Advantages

Ample room for growth. Cincinnati has abundant space for expansion. The encircling hills offer ample room for growth. Moreover, the suburbs can be located within easy reach of the city's business center by trolley and railroad train.

Good climate. The city is favored in climate, from an industrial point of view. The surrounding hills protect the city from

destructive winds, and modify the effect of storms; Cincinnati is not visited by the Western tornadoes, or the storms of the North and South. The wind direction is prevailingly from the southwest. Moreover, the temperature maintains a happy medium; her winters are comparatively mild, the mean temperature being 33.6°; her summers are rarely extremely warm, the mean temperature being 73.5°. The average rainfall for the year is 48.02 inches, and the precipitation is well-distributed seasonally, summer being the wettest season and autumn the dryest. Cincinnati's climate is healthful, the annual death rate is 20 per 1000. Strangers coming to the city become acclimatized very readily.

Public improvements. An abundant supply of water, with a thoroughly modern and scientific filtration plant, excellent shipping facilities and a fine street-lighting equipment, are valuable industrial assets of which Cincinnati can boast.

Central location. Cincinnati's location with respect to other large cities is quite advantageous. It is about 750 miles from New York, 600 miles from Washington, 300 miles from Chicago and St. Louis, 640 miles from Baltimore, 250 miles from Cleveland. Furthermore, Cincinnati is the nearest large city to the center of population (which, according to the last census, is located near Bloomington, Ind.), and is therefore a good base for supplies.

Grain and coal center. Having a very extensive distributive outlet to all the Southland, Cincinnati has become one of the country's most important grain centers. This city is, in addition, the soft coal center of the United States, taking into consideration production, availability and geographical location. Ohio, Michigan, Illinois, Indiana, Kentucky, Tennessee, Alabama, Pennsylvania and West Virginia furnished 85 per cent of the total amount of coal produced in the United States in 1909;[15] these coal regions are within a radius of 300 miles from Cincinnati. In 1910 Cincinnati received more coal than ever before in her history, 20 per cent more than in 1909. The improvement of the Ohio River, particularly the building of Fernbank Dam, and the extension of railroad lines to the east, west and south, will combine to give Cincinnati still greater advantage in location in respect to the availability of cheap fuel.

[15] U. S. Government Report on "The Production of Coal," 1910.

RIVER IMPROVEMENT

Shipping facilities. Cincinnati's advantageous railroad connections have already been mentioned. The city is connected with the south, east and west by fifteen railroads. But the river has always been the chief factor in Cincinnati's progress. The harbor at Cincinnati is very superior, the current of the river is about 3 miles an hour, and there are no shoals or reefs to prevent the landing of boats.

Fernbank Dam. This dam, a government project just recently finished, is destined to have an important effect on the city's future commercial progress. Heretofore the low stage of water in the summer months has frequently been the source of great inconvenience and a great loss of money to manufacturers. This dam affords a lake for harbor purposes the year round at Cincinnati, and will produce a large amount of water-power for electrical energy, which can be utilized for manufacturing purposes, and will therefore be of very great value to the city.

Improvement of the Mississippi system. Fernbank Dam is but one of the many dams which the government is now building or planning to build. It is estimated that, in order to secure a 9-foot stage from Pittsburg to Cairo, Ill., about seventy-five dams will be required, at a cost of about $75,000,000. At the present time the Ohio River is navigable at Pittsburg, on an average, only about eighty-one days during the year. Since the region about Pittsburg is one of the greatest, if not the greatest, freight-producing center of the country, this is a serious detriment. It is planned, by means of collapsible dams, to store up a supply of water during flood times, and thus make navigation possible the year round. By holding back the waters of the Monongahela, Kanawha, Allegheny, Youghiogheny, and the numerous small tributaries of the Ohio, the disastrous effects of floods will also be lessened, and a large amount of power will be developed at the dams. With the 9-foot stage, it will be possible to use less powerful steamers in bringing barges down the river, each boat taking fewer barges, with less capital invested at less risk.

The freight carried by the Ohio River system forms the bulk of the Mississippi system tonnage. It has been estimated that with the improvement of the Mississippi River system, and the completion of the Panama Canal, freight can be sent by water

down the Ohio and the Mississippi Rivers, through the Panama Canal, and around to the Pacific Coast at about one-fourth the cost for sending it across the country by rail. This being the case, Cincinnati's position is strategic, for she is the nearest large city to the center of population, central to the fertile Ohio valley, a very important grain center, and has easy access to the ore deposits of Northern Michigan and the great soft coal regions of the United States. With a clear passage from Pittsburg to the Gulf, river commerce should increase enormously, and Cincinnati's industrial progress should be correspondingly nurtured.

STROPHOMENA AND OTHER FOSSILS FROM CINCINNATIAN AND MOHAWKIAN HORIZONS, CHIEFLY IN OHIO, INDIANA, AND KENTUCKY*

Aug. F. Foerste

The Stones River, Black River, and Trenton limestones, in the area crossed by the Cincinnati geanticline, are essentially limestone formations, while the Cincinnatian, including the Richmond, consists of alternations of thin limestones with variable amounts of argillaceous matter. This contrast is emphasized if the Catheys be placed at the base of the Cincinnatian, instead of at the top of the Trenton.

At various periods during the deposition of these strata, argillaceous elements predominated, and during the most important of these, judging from the comparative absence of fossils, life must have been nearly extinct over areas by no means inconsiderable. These periods of local extinction of life, or the withdrawal of life to narrower areas, were followed by others during which life spread and again covered more or less of the area from which it had retreated. In some cases, the returning life came from a source quite different from that to which the former life had retreated, so that a relatively new fauna was introduced into the territory under consideration. Such a change of faunas gives the intervening argillaceous, more or less unfossiliferous strata their chief importance from the standpoint of stratigraphical geology.

One of the most important of these comparatively unfossiliferous sections of argillaceous strata is that to which the name Paint Lick was applied. This forms the lower part of the Garrard formation as originally defined by Marius R. Campbell, the upper part corresponding to the Mount Hope member of the Maysville, stratigraphically. The Paint Lick member of the original Garrard formation may be traced from Bath county south-

* Published by permission of Professor C. J. Norwood, Director of the Kentucky Geological Survey. Plates I to VI are the property of the Survey.

westward as far as Boyle county, in Kentucky. West of this line of outcrop, the Paint Lick member apparently is replaced by more fossiliferous strata, but where it is characteristically developed, the overlying Mount Hope and Fairmount faunas are in striking contrast with the underlying Eden faunas. This contrast is greatest southward, in Madison, Garrard, Lincoln, and Boyle counties, where that part of the Eden below the Paint Lick horizon was grouped under the term Million, on account of its different faunal expression from that exhibited by the Eden at Cincinnati. At Cincinnati, however, where the typical Paint Lick member is absent, the McMicken member bridges, in part, the faunal break.

Moreover, the central and southern Kentucky representatives of the Mount Hope and Fairmount members at Cincinnati belong to the southern or Maury phase of the Fairview division of the Maysville. This is another reason why the contrast between the faunas above and below the Paint Lick horizon appears greatest southward, where the intermingling of faunas was least possible.

Another important, practically unfossiliferous, argillaceous section is that represented by the Tate member, between the Fairview and McMillan divisions of the Maysville. This may be traced all the way from Casey and Boyle counties, in central Kentucky, to Adams county, in Ohio. In this case the greatest contrast between the overlying and underlying faunas again is seen farther southward, in Madison, Garrard, Lincoln, Boyle, and Marion counties, while at Cincinnati the contrast is considerable, but not as striking. Moreover, in the counties of central Kentucky just named, that part of the McMillan section which overlies the Tate member consists chiefly of dove-colored limestone layers, which are in rather striking contrast lithologically with the stratigraphically equivalent strata northward. For this part of the McMillan section, in central Kentucky, the term Gilbert member has been adopted. Stratigraphically it corresponds most nearly to the Corryville member northward.

Another argillaceous horizon forms the lower half of the Arnheim, and has been called the Sunset division of the latter. This horizon can be recognized most readily between Adams county, in Ohio, and Stanford, in Lincoln county, Kentucky. Northward, this lower, or Sunset division of the Arnheim, is moderately fossiliferous, but between the southern margin of Clark county

and Stanford, the lower part of the Arnheim is characterized by an entirely unfossiliferous shaly rock overlaid by a thinner section of dove-colored limestones, and the latter by the richly fossiliferous strata forming the upper part of the Arnheim. In central Kentucky, the Arnheim fauna, overlying the argillaceous Sunset division, is strikingly different from the underlying fauna of the McMillan, while northward, in Ohio and Indiana, the lower Arnheim fauna bridges the gap between the upper Arnheim and the Mount Auburn.

The stretch of territory between Boyle county, in central Kentucky, and Adams county, in Ohio, was an important one in the distribution of faunas, especially during the deposition of the Eden and Maysville. There is abundant evidence that during this time there was free access from the seas southwest of central Kentucky to those northeast of this area, across the region now traversed by the Cincinnati geanticline. Frequently, there is a greater similarity of faunas for many miles from Boyle county northeastward toward Adams county than for a much shorter distance northwestward from this line. This is true especially during the deposition of the lower and upper part of the middle Eden, and also of the Mount Hope and Fairmount. It is illustrated by the early introduction of *Strophomena maysvillensis* along this line, during the Mount Hope, and by the distribution of *Orthorhynchula linneyi*, *Escharopora hilli*, and *Cyrtoceras vallandinghami* during the later part of the Fairmount. The distribution of the Rogers Gap fauna, at the base of the Eden section as exposed in central Kentucky, is chiefly along this channel. Even the typical Mount Auburn fauna, extending northward to Cincinnati and Lebanon, finds a greater extension in Clermont, Brown, and Adams counties in Ohio, and in Lewis, Fleming and Bath counties in Kentucky, than in the western parts of Hamilton and Butler counties, in Ohio, or in any part of Indiana.

The channel across the region later occupied by the Cincinnati geanticline, by way of Casey, Boyle, Lincoln and Garrard counties, was open also during the deposition of the upper part of the Arnheim, as is attested by the distribution of *Platystrophia ponderosa*, *Rhynchotrema dentata*, and to a certain extent by the distribution of *Leptaena richmondensis* during this period. It must have been open also for a brief period at the close of the Waynesville or the beginning of the Liberty, while the *Beatricea* and coral

fauna of Nelson, Washington, Marion, and Casey counties made its way as far eastward as Ophelia, 4 miles north of Richmond, in Madison county, Kentucky.

Another great period of deposition of argillaceous strata occurred during the Waynesville. Here, again, unfossiliferous, argillaceous deposits characterize the lower part of the member, while a return of fossil faunas takes place during the deposition of the upper part. In Marion, Boyle, Casey, Lincoln, Garrard, Madison, and Clark counties, in central Kentucky, no fossils occur in the lower part of the Waynesville, unless a thin, richly fosilliferous strip, often less than 2 feet thick, at the very base of the formation, be regarded as of Waynesville age. As the lower, unfossiliferous part of the Waynesville is traced northward, on the western side of the Cincinnati geanticline, it first becomes moderately fossiliferous, as far as Oldham county. From this point northward the abundance of fossils and the number of species rapidly increases. Similar features are seen on the eastern side of the Cincinnati geanticline, where the fossils are only moderately numerous in the lower part of the Waynesville, in Montgomery and Bath counties, in Kentucky, but become abundant farther northward.

The Fort Ancient and Clarksville divisions of the Waynesville can be traced only a short distance south of the Ohio River, on the eastern side of the geanticline. The Blanchester division, however, has been traced as far as Owingsville, in Bath county. On the western side of the Cincinnati geanticline, the Fort Ancient and Clarksville divisions have not been traced south of Trimble county. The characteristic fossils of the Blanchester division have not been seen south of the northern part of Jefferson county, in Indiana, although the upper part of the Waynesville member, as exposed at Madison, is believed to belong to this division. The Liberty, however, extends far southward, to the vicinity of Raywick, in the western part of Marion county, Kentucky, On the eastern side of the geanticline, the Liberty fauna also may be traced southward beyond the Ohio River, to Owingsville, in Bath county, Kentucky.

From Bullitt county southward, the upper part of the Waynesville or the basal part of the Liberty is characterized by the presence of numerous specimens of *Columnaria*, *Calapoecia*, *Tetradium*, and a variable number of specimens of *Beatricea*. This

coral horizon may be traced southward as far as Marion, Boyle, and Casey counties, and eastward to Lincoln, Garrard, and Madison counties. At these more southern localities it forms a thin wedge, only a few feet thick, between the underlying unfossiliferous argillaceous Waynesville strata and the overlying unfossiliferous argillaceous strata which northward merge into the Saluda of southern Indiana.

The Saluda represents another great period of deposition of argillaceous strata. Where it is more typically developed, in Jefferson and Clark counties, in Indiana, and in Trimble, Oldham, Jefferson, and Bullitt counties, in Kentucky, it is nearly or entirely unfossiliferous. This is practically its character also southward, in Nelson, Washington, and Marion counties, although there are local areas within which *Tetradium* and *Stromatocerium* are abundant at the extreme top of the Saluda. A relatively thin fossiliferous layer, the Hitz layer, occurs immediately above the Saluda also between the eastern part of Jefferson county, in Kentucky, and the southern limit of Ripley county.

From the vicinity of Madison, in Indiana, the fossil content of the Saluda, especially of the upper two-thirds, increases gradually northward, but as far as the extreme northern edge of Ripley county there is a band of shaly, unfossiliferous strata in the lower third of the Saluda, which is very characteristic of this horizon. North of Weisburg and Ballstown, in Ripley county, the Saluda has not as yet been traced with care. Owing to the rapidity of the increase of the fossil content on passing northward through Ripley county, and owing to the accompanying lithological changes, it is highly desirable that a more detailed study be made to determine what are the exact stratigraphical equivalents of the different parts of the Saluda north of Ripley county.

For the present, it may be stated that while the lower part of the Waynesville was being deposited in Ohio and Indiana, the south-central part of Kentucky was practically devoid of life. Only the upper part of the typical Waynesville fauna reached Jefferson county, in Kentucky, and only the lower part of the Liberty reached Marion county, unless the great coral horizon is to be regarded as belonging to the top of the Waynesville. Before the invading argillaceous deposits of the Saluda, the Liberty fauna retreated northward to the Ohio and Indiana basin, from

which the Waynesville invasion formerly had progressed southward.

The Waynesville and Liberty, taken together, contain that part of the Richmond fauna along the Cincinnati geanticline which most nearly is related to the Mississippi Valley Richmond. The two formations appear more closely linked together in their fossil content than the other Richmond formations. For that reason the term Laughery formation is proposed for the Waynesville and Liberty as exposed along Laughery Creek in Ripley county, Indiana.

On the eastern side of the Cincinnati geanticline, the Blanchester division of the Waynesville bed may be traced by means of typical fossils as far as Owingsville, in Bath county, and the base of the Liberty is fossiliferous as far as the same locality. Here again it is the strata along the plane of junction between the Waynesville and Liberty which may be traced farthest southward.

The great coral horizon at the top of the Waynesville or at the base of the Liberty may be traced from the western side of the Cincinnati geanticline eastward as far as Ophelia, 4 miles north of Richmond, in Madison county, and as far as the mouth of the Red River at the northeastern edge of this county. Here it may be seen that the overlying strata are unfossiliferous southward, but gradually become more and more fossiliferous northward, simulating in this respect the features shown by the Saluda on the western side of the geanticline.

Owing to the considerable lithological and accompanying faunal differences between the Cincinnatian strata as exposed in Ohio and Indiana, and their approximate stratigraphical equivalents in central Kentucky, it may prove convenient, locally, to recognize only the greater subdivisions of the Cincinnatian strata, as proposed at the typical section, at Cincinnati, Ohio, and to adopt a somewhat different set of subdivisions southward.

The terms employed on the following pages are indicated in the following table.

Cincinnatian	Richmond		Elkhorn	
			Whitewater	
			Saluda	
		Laughery	Liberty	
			Waynesville	
			Blanchester	
			Clarksville	
			Fort Ancient	
		Arnheim	Arnheim	
			Oregonia	
			Sunset	
	Maysville	McMillan	Mt. Auburn	
			Corryville	Gilbert
			Bellevue	Tate
		Fairview	Fairmount	
			Mt. Hope	
				Paint Lick
	Eden		McMicken	
			Southgate	Million
			Economy	Rogers Gap
			Fulton	
	Catheys		Catheys	
			Nicholas	
			Greendale	
Mohawkian and Chazyan	Lexington		Cornishville	
			Perryville	
			Faulconer	
			Paris	
			Wilmore	
			Logana	
			Curdsville	
	High Bridge		Tyrone	
			Oregon	
			Camp Nelson	

Strophomena incurvata, Shepard[1]

XI

(*Plate XI, Figs. 7, 9 A, B, C*)

Brachial valve usually moderately convex, valves 40 mm. in diameter, having a convexity of 7 to 10 mm. Pedicel valve moderately concave, the concavity varying from 3 to 5 mm. in shells 40 mm. in width. Postero-lateral angles usually varying between 75 and 85 degrees, although occasionally the shell is sufficiently extended along the hinge-line to produce an angle of 60 degrees. The more quadratic forms are more common. In the specimens from Cloche Island, the shell frequently is wrinkled along the hinge-line. Usually these wrinkles are strongly oblique, making angles of 25 to 30 degrees with the hinge-line, although occasionally the angles are as low as 15 degrees, and still more rarely some of the wrinkles nearest the postero-lateral angles form angles as high as 60 degrees, resembling the more vertical wrinkles seen in *Strophomena vetusta.* Radiating striae on the brachial valve, usually about 7 or 8 in a width of 2 mm., where there is no intercalation of additional striae. In those parts of the shell where numerous additional striae have been intercalated a short distance posteriorly, the number of radiating striae may reach 12 in a width of 2 mm. Striae usually subequal, or alternating in size. Occasionally, every fourth striation is more conspicuous, being stronger and more elevated. Striations transverse to the radiating striae, very fine. No evidence of concentric wrinkling.

Hinge area on pedicel valve with a height of 3.5 mm. in specimens 40 mm. in width; decreasing in height slowly until near the postero-lateral angles. Margins of the delthyrium forming an angle of about 80 degrees. Deltidium low, frequently with the sides flattened so as to produce a more angular median line than is usual in other species of *Strophomena.* This angularity is best exhibited in the specimens from Cloche Island, but it is seen also in some of the Kentucky specimens. The more evenly convex deltidia also occur. The divergent sides of the deltidium extend diagonally forward from the median line for a distance of 5 or 6 mm.; their distal terminations forming the dental plates. The latter extend from 1 to 1½ mm. beyond the anterior margin of

[1] *American Jour. Sci.*, vol. xxxiv, p. 144, 1838.

the hinge-area, and coalesce with the lateral, sharply raised border of the muscular area. This muscular area varies from rounded rhomboidal, to nearly circular in outline. The muscular area rises rather gradually toward its antero-lateral borders, but the slope from these borders toward the body cavity is abrupt. The chief characteristic of the muscular area is the presence of eight to ten rather indistinct radiating striae within the area of each of the diductor scars, separated by a low median elevation. This is the flabellate type of scar, in which the anterior and posterior divisions of the diductor scars are not distinctly differentiated. The entire interior of the body cavity, outside of the muscular area, is minutely granulose. In the case of very thin valves, in which the radiating striae ornamenting its exterior may be readily detected also on the interior surface, these granules are arranged along lines corresponding to the grooves between the exterior striae, but on the ordinary, thicker valves, these granules are arranged more irregularly.

The antero-lateral raised borders of the muscular area, in case of the pedicel valve, approach anteriorly within about 3 mm. of each other and then curve sharply backward toward the lateral margins of the low median elevation which traverses the area from front to rear. This leaves an anterior gap, which is very characteristic of all species of *Strophomena*. The muscular area is surrounded on all sides, except at the gap, by a series of short ridges, arranged with their axes parallel to the radiating lines. These short ridges sometimes merge into longer, straight ridges, especially posteriorly, toward the hinge-area, but usually they are discrete. On each side of the gap, these short ridges cover an area extending about 2 mm. anterior to the raised border of the muscular area. Laterally, these ridges cover an area extending from 4 to 5 mm. from the lateral border of the muscular area, and they occupy the space directly posterior to that just described, as far as the hinge-area.

The interior of the pedicel valve is thickened within a short distance of the anterior and lateral margins. Anteriorly, the maximum thickening is about 4 or 5 mm. from the edge of the shell. Laterally, this thickening becomes less pronounced, and the maximum thickening approaches to within 2 mm. of the lateral margin, near the hinge-area. Occasionally this thickening equals fully 1½ mm. anteriorly, but usually it is less than 1 mm., and may

be quite inconspicuous. This thickened region is crossed radially by rather distant grooves which may be traced posteriorly for a short distance, sometimes about half the distance from the thickened region to the muscular area. Toward the margin of the valve, these grooves frequently branch several times.

Excepting within the region of the muscular area, the interior of the brachial valve is minutely granulose, with indications of short radial ridges corresponding in position to those already described in case of the pedicel valve. A low elevation extends from front to rear across the muscular area. Two low but rather narrow and sharp ridges, 6 to 7 mm. long, and 5 mm. apart, extend across the middle of the valve, in a direction from front to rear. These ridges correspond to the outer pair of the four ridges limiting the median vascular sinuses in such species as *Strophomena vetusta*. The anterior and posterior adductor scars are rather indistinctly defined. The cardinal process is bifid, the two lobes being divergent; the posterior faces of these lobes are crossed by a groove. The crural plates are strongly divergent, and become subparallel to the hinge-area within $1\frac{1}{2}$ mm. of the latter.

Strophomena incurvata was described by Shepard from the vicinity of Green Bay, Wisconsin, where it occurs in strata regarded as equivalent to the Black River formations.

In the lower part of the equivalent strata of Minnesota, *Strophomena incurvata* is associated with *Rafinesquina minnesotensis, Orthis tricenaria, Dinorthis deflecta, Hebertella bellarugosa, Dalmanella subaequata* with several of its varieties, and *Rhynchotrema inaequivalve*. All of these species, with the exception of *Dinorthis deflecta*, are represented also in the upper part of the Black River section of Minnesota, either by typical specimens or by varieties of the species. *Dinorthis pectinella* is listed only from the upper part of the Black River in Minnesota.

The association of *Strophomena incurvata* with *Orthis tricenaria, Dinorthis pectinella*, and *Hebertella bellarugosa* is found on Cloche Island, northeast of Little Current, west of Georgian Bay, in Ontario. South of Cloche Island, on the northeastern edge of Goat Island, *Strophomena incurvata* is associated with *Orthis tricenaria, Dinorthis pectinella*, and species of *Carabocrinus* and *Cleiocrinus*. These are typical Black River exposures.

In central Kentucky, the large typical specimens of *Orthis tricenaria* and *Dinorthis pectinella*, associated with *Carabocrinus*

and *Cleiocrinus*, occur in the Curdsville bed. *Hebertella bellarugosa* is absent at this horizon. I have never found any species of *Strophomena* at this horizon, but Mr. E. O. Ulrich listed *Strophomena filitexta* ("Correlation of the Lower Silurian," *Am. Geol.*, vol. i, p. 108, 1888), a species now included under *Strophomena incurvata*, from the Curdsville. If the Curdsville member finds any approximate equivalent in the Ordovician section along the northern part of Lake Huron, it must be in the upper part of the Black River section, as exposed on Goat Island. There are sufficient differences in the faunas, however, to make exact equivalency uncertain.

The most typical specimens of *Strophomena incurvata* in central Kentucky are found in the Tyrone member. At High Bridge, between 24 and 29 feet below the clay at the top of this member, there is a richly fossiliferous horizon at which *Strophomena incurvata* is abundant. Here it is associated with *Rafinesquina minnesotensis*, and small specimens referred to *Orthis tricenaria*. I have never found *Dalmanella subaequata*, *Dinorthis deflecta*, or *Hebertella bellarugosa* at this horizon, although Mr. Ulrich lists the first two species from the richly fossiliferous horizon here under consideration, and the last species from the upper, cherty part of the Tyrone. The Oregon member contains very few fossils; no species of *Strophomena* has been found.

Specimens of *Strophomena* closely resembling *Strophomena incurvata* occur at several horizons in the Camp Nelson member of the Stones River group; the only ones recorded were from 35 and 95 feet below the top of this member. The lower part of this division, as exposed near Camp Nelson, Kentucky, has not been studied. At High Bridge, *Rafinesquina minnesotensis*, *Orthis tricenaria*, *Hebertella bellarugosa*, and *Rhynchotrema inaequivalve* have been collected between 130 and 140 feet below the top of this division. *Dinorthis deflecta* and *Dalmanella subaequata* are known from 120 feet below the top. Judging from the published lists of fossils from the equivalent strata in southern Tennessee ("Columbia folio," U. S. Geol. Surv., Hayes and Ulrich, 1903), the Camp Nelson member corresponds to the Lebanon and Ridley members of the Stones River group. Apparently most of the exposed part of the Camp Nelson member, at High Bridge, belongs to the Lebanon member. In Tennessee,

Strophomena incurvata is listed also from the Pierce division of the Stones River group.

Strata closely resembling the very fine-grained limestones characterizing the High Bridge limestone in central Kentucky, occur also in Ontario, along the northern part of Cloche Island, along the railroad track, below undoubted Black River strata. In the absence of fossils, however, their exact equivalency to Kentucky or Tennessee strata must remain for future determination, although for the present they are regarded as of Lowville age.

Strophomena incurvata makes its first appearance in the Pierce limestone of Tennessee. Thence it ranges upward to the base of the Carters limestone. Since the lower divisions of the Stones River group are not known from the northern part of the Mississippi basin or from the region bordering the Great Lakes, this evidence favors the introduction of *Strophomena incurvata* from some other direction, probably the south or southeast, although during late Stones River times and during the deposition of the Black River, this species spread to Iowa, Wisconsin, Minnesota, Manitoba, and the northern parts of Lake Huron. During the deposition of the Black River, it even reached New York and Canada.

The finely striated species of *Strophomena*, with flabellate muscular scars in the pedicel valve, typified by *Strophomena incurvata*, are unknown, in the areas traversed by the Cincinnati geanticline, in the Trenton, Eden, and Maysville formations, but return in the form of *Strophomena neglecta* and *Strophomena planodorsata* in the Waynesville and closely related horizons of the Richmond. *Strophomena planodorsata* replaces *Strophomena neglecta* northwestward, in Minnesota and neighboring states, and extends southward to western Tennessee.

Strophomena vicina, Foerste[2]

(*Plate VII, Fig. 2, magnified*)

Shells varying from 30 to 35 mm. in width along the hinge-line, occasionally attaining a width of 40 mm. The ratio of the width to the length usually varies from six-tenths to seven-tenths.

[2] *Denison Univ. Bull.*, vol. xiv, p. 317, Plate VII, Figs. 12 *A*, *B*, 1909.

Postero-lateral angles varying from 70 to 85 degrees, giving rise to two types of outline, in one of which the postero-lateral angles vary from 70 to 75 degrees, and the shell is broadly and transversely semi-elliptical. In the other type of shell, the postero-lateral angles equal about 85 degrees, and the outline is subquadratic. Apparently the shells with the more acute postero-lateral angles are less convex, while the convexity of the more quadratic forms is greater. This convexity usually equals 4 or 5 mm. in the former group and 6 or 7 mm. in the latter. The brachial valves are evenly convex from front to rear, with a scarcely perceptible depression about a millimeter from the beak. The concavity of the pedicel valve varies from 1 to 2 mm. Oblique wrinkling of the shell along the hinge-line is rare, and not at all characteristic of the species. In one specimen these wrinkles formed an angle of about 40 degrees with the hinge-line. The number of radiating striae usually equals 6 or 7 in a width of 2 mm., but may be as low as 5, and as high as 9 or 10, in the case of individual specimens.

Deltidium of the pedicel valve broadly convex, the teeth extending only a short distance, usually less than a millimeter, beyond the hinge-area. Muscular area rounded, subrhomboidal, with a strongly raised lateral border posteriorly, becoming less conspicuous anteriorly, where it is deflected toward the front, leaving a gap varying from 2 to 3 mm. in width. The muscular area is traversed by a low, broad, median elevation, bearing indications of the attachment of the adductor muscles posteriorly. There is a tendency toward a linear depression on each side of this median elevation, extending forward through the gap. The area of attachment of the diductor muscles frequently is divided by a more or less distinct ridge into two parts, of which the one nearest the postero-lateral border is the narrowest. There are no radiating striae of about equal size and even distribution as in the case of *Strophomena incurvata.* The type of muscular area seen in *Strophomena vicina* is that typified by *Strophomena planumbona,* of which it may be regarded as a precursor. The interior of the body cavity is comparatively smooth. There is a slight thickening of the valve about 4 mm. from the anterior margin, this thickening usually equalling less than a millimeter. It is crossed by vascular grooves, branching anteriorly and merging along the margin into the numerous grooves corresponding, in position, to the radiating striae on the exterior of the shell.

In the case of one brachial valve, the inner margins of the two lobes of the cardinal process are almost in contact with each other, forming subparallel ridges along the posterior faces of the lobes. Broad and shallow grooves separate these ridges from the postero-lateral margins of the lobes, which practically are in contact with the crural ridges. These features may not be characteristic of the species. In another specimen there is a broad median elevation separating two obovate muscular scars, which posteriorly are traversed by short, moderately radiating lines, and anteriorly give rise to the two outer, and more conspicuous subparallel ridges of the group of four which limit the median vascular sinuses in the genus *Strophomena.*

The type specimens were collected on the farm of C. H. Bowyer, half a mile northeast of Becknerville, in Clark county, Kentucky. Specimens occur also at several localities from a mile to a mile and a half northwest of Becknerville, on the road to Pine Grove. The station labelled Pine Grove on the Richmond sheet of the United States Geological Survey, at present is named Colby. Near Becknerville, *Strophomena vicina* is associated with *Dinorthis ulrichi*, *Hebertella frankfortensis*, and *Rhynchotrema inaequivalve.* The same horizon is exposed at Flanagan. Here the following section is exposed in descending order. The rock is limestone. Only the ranges of the included fossils are indicated.

Numerous specimens of *Allonychia flanaganensis*, 11 cm. in length from the beak along the umbonal ridge, hinge area 6.5 cm. in length extending 5 to 8 mm. anterior to the tip of the beak, hinge area 4 to 6 mm. high, shell surface apparently smooth.

Granular limestone..11 ft.

Granular limestone, one large *Hebertella frankfortensis*........5 ft. 6 in.

Road crossing, a mile and a half northeast of Flanagan.

Granular limestone with *Rhynchotrema inaequivalve*...........5 ft. 6 in.

Road crossing.

Granular limestone northward, clayey with abundant chert fragments southward..3 ft. 6 in.

Chiefly weathered to clay, with argillaceous, fine-grained rock masses remaining in places. At this and the immediately overlying horizon, the typical Flanagan chert makes its appearance ....5 ft. 6 in.

Road crossing.

Strophomena, very thin, finely-striated specimens which may not belong to *Strophomena vicina.* Also a variety of *Rhynchotrema inaequivalve*...6 in.

Numerous bryozoans and a few *Rhynchotrema*....................5 ft.
Strophomena vicina fairly common in a coarse-grained limestone. . 1 ft. 6 in.
Dinorthis ulrichi, Rhynchotrema inaequivalve, and *Hebertella frankfortensis* range throughout this section. *Strophomena vicina* occurs only within one foot of the top..........................6 ft.
Interval...1 ft.
Crossing of farm road over railroad.
Interval..2 ft. 6 in.
Short railroad bridge, No. 31.
Loose cherty specimens of *Dinorthis ulrichi* and *Rhynchotrema* near the top and *Dalmanella* at the base.......................5 ft. 6 in.
One *Strophomena vicina* and *Rhynchotrema* in place..................2 ft.
Rhynchotrema and *Herbertella frankfortensis*......................9 ft.
Flanagan railroad station.

This section undoubtedly belongs to the upper part of the Lexington limestone, probably the Paris bed. The nearest known outcrop of the Perryville bed is 28 miles southwestward, at Toddville, in Garrard county, and it is not known at present whether the Perryville bed and the overlying Cornishville bed may be traced beyond Toddville, northward; hence a more exact correlation is impossible. An interesting feature of the section along the railroad north of Flanagan is that it suggests the presence of *Strophomena* at a horizon 15 feet lower than that at which it is associated with *Dinorthis ulrichi.* Going northward along the railroad, *Hebertella frankfortensis* and *Rhynchotrema inaequivalve* occur at still higher levels, but the possibility of faulting can not be excluded.

It should be noted that at Flanagan, the Flanagan chert belongs immediately above the *Strophomena vicina* and *Dinorthis ulrichi* horizon. This is true also 4 miles northwest of Flanagan, at the northern edge of the C. H. Bowyer farm, nearly a mile north of Becknerville.

Strophomena vicina, associated with *Dinorthis ulrichi* and *Rhynchotrema inaequivalve,* occurs in the upper part of the Lexington limestone also, in the western edge of Valley View, halfway between Flanagan and Toddville. Twenty miles northwest of Flanagan, the same association of fossils, including also *Hebertella frankfortensis,* occurs at the G. C. Gorham quarry, 4 miles northeast of Lexington, on the Newtown pike. Less than 9 miles northwest of the last locality, half a mile west of Georgetown, on the Franklin pike, *Strophomena vicina* and *Dinorthis ulrichi* are found associated, but both are very rare.

In Boyle county, and in the southern half of Mercer county, in Kentucky, the top of the Lexington limestone is formed by a rather coarse-grained, more or less cross-bedded, gray limestone, 4 or 5 feet in thickness, overlying a fine-grained limestone section, about 20 feet thick. The fine-grained limestone forms the Perryville member of the Lexington limestone. The upper part of the Perryville member, varying from 5 to 8 feet in thickness, is very hard, breaks with a splintery fracture, has a dove color, and frequently is marked with little whitish spots, which caused W. M. Linney to apply the term Upper Birdseye Beds to this part of the Lexington section. Westward at Perryville, Nevada, and Cornishville the underlying part of the Perryville bed is darker, softer, and much more richly fossiliferous. In fact, it is the richest fossil horizon in the Lexington section. Eastward, at Danville, a mile and a half northwest of Faulconer, and near Harrodsburg, this lower part of the Perryville section is whiter and even more richly fossiliferous. It contains the fauna described by Ulrich from the vicinity of Danville and Burgin and forms the Faulconer division of the Perryville.

The coarse-grained limestone, overlying the Perryville member, may be called the Cornishville limestone, from the village in Mercer county, 11 miles north of Perryville. It contains *Strophomena vicina*, *Dinorthis ulrichi*, *Hebertella frankfortensis*, *Platystrophia colbiensis*, *Rhynchotrema inaequivalve*, and *Stromatocerium canadense*. *Strophomena vicina* occurs in the Cornishville limestone at Cornishville, 9 miles west of Harrodsburg; at the railroad crossing, 2 miles northwest of Harrodsburg; at several localities along the railroad southeast of Harrodsburg, as far as the county line; and 2 miles east of Harrodsburg; all in Mercer county. In Boyle county, it occurs at several localities within 3 miles southeast of Perryville, and between Perryville and Atoka.

The Perryville bed may be identified 11 miles northeast of McAfee, on the farm of Mrs. Ben Williams, 2 miles south of the Crow distillery at Glenn Creek Station. Here the more typical part of the Perryville section is 7 feet thick. The rock resembles the darker, fine-grained limestone forming the lower part of the Perryville section at Cornishville, and contains *Isochilina jonesi*, *Loxoceras milleri*, and other fossils. The immediately underlying whitish siliceous limestone, 6 feet thick and full of gasteropod

remains, also may belong to that part of the Perryville section, which between Harrodsburg and Danville is characterized by the abundance of silicified gasteropod remains. The Cornishville limestone has not been identified here.

About 9 miles northeast of the last locality, 4 miles north of Versailles, along a road reached by going from Wallace a little over a mile westward and then a mile and a half southward, the Perryville bed is represented by residual boulders of a very white, dense limestone containing *Orthorhynchula linneyi*, *Oxydiscus subacutus*, *Isochilina jonesi*, and a species of *Tetradium*. This rock resembles the very white rock at the top of the Perryville bed, but similar rock, full of silicified fossils, occurs in the lower part of the Perryville bed, between Harrodsburg and Danville. The gasteropod layer also is represented, in this area, southwest of Wallace, by large boulders. Similar boulders occur 2 miles southeast of Wallace, near the Mount Vernon pike, and 1 mile northeast of Versailles, along the railroad.

Seven miles north of Versailles, three-quarters of a mile southeast of Ducker Station, the siliceous gasteropod layer varies from 4 to 6½ feet thick. It is overlaid by very white, fine-grained limestone containing specimens of *Leperditia*, evidently belonging to the Perryville bed. This limestone is only 1 foot thick, and is overlaid by a foot and a half of nodular argillaceous limestone, which may belong to the same horizon.

The very white limestone characterizing the upper part of the Perryville bed is seen also southwest of Frankfort, opposite the western entrance to the Taylor grounds. Loose fragments resembling the gasteropod layer are seen. These outliers of the Perryville limestone suggest an unconformity between the Lexington and Winchester limestones. Moreover, the gasteropod layer, if it represents the lower part of the Perryville bed, suggests an overlap of the Perryville on the Paris bed, thinning out northeastward. This will account for an absence of any trace of the Perryville bed northeast of a line connecting Frankfort and Toddville. Hence it is not believed possible to correlate the lower, richly fossiliferous part of the Perryville bed, full of gasteropods, with the Flanagan chert of the Richmond folio.

The upper part of the Paris bed, in Woodford, and Franklin counties, is a rather coarse-grained, often cross-bedded, and more or less phosphatic limestone. This is underlaid by a more fossil-

iferous section, and about 55 feet below the top of the Paris bed there is a layer of rather fine-grained argillaceous limestone, about 10 feet thick, in which *Strophomena vicina* occurs, associated with *Platystrophia colbiensis.* This *Strophomena vicina* horizon, which is distinctly below the top of the Paris bed, may be traced from Glenn Creek and Frankfort westward to Bridgeport and Benson.

Eastward, this lower *Strophomena vicina* horizon may be traced to Versailles; 5½ miles northwest of Versailles, a mile and a half west of McKee Stop on the Frankfort traction; nearly 2 miles northwest of Midway; also 3½ miles south of Versailles, on the road to Pinckard.

The argillaceous, fine-grained limestone, characteristic of this lower *Strophomena vicina* horizon westward, can not be traced beyond Versailles, but the *Strophomena vicina* horizon maintains the same relative position in the Paris bed as far east at least as Brannon, in the north-central part of Jessamine county, and the western part of Fayette. Sometimes *Strophomena vicina* occurs not in the fine-grained limestone layer already discussed, but immediately beneath. Not infrequently *Stromatocerium canadense* occurs immediately above the *Strophomena vicina* horizon. It occurs in this association about 3 miles southwest of Frankfort, east of the home of B. B. Graves on the Lawrenceburg pike; south of Glenn Creek; 3½ miles south of Versailles, on the road to Pinckard; at several localities near Brannon; and at the Gorham quarry, 4 miles northeast of Lexington, on the Newtown pike. At the first and last of these localities, *Strophomena vicina* is associated with *Dinorthis ulrichi,* which suggests that this fossil also occurs at two horizons: in the Cornishville limestone and also about 50 or 60 feet below the top of the Paris bed. So far, *Strophomena vicina* has not been found below the lower one of these horizons.

At the depot, at Lair Station, in the southern part of Harrison county, *Strophomena vicina* occurs in the Paris bed, 18 feet below the top of the Lexington limestone. The upper part of the Lexington limestone here is almost unfossiliferous. Half a mile west of Pine Grove, in the western edge of Clark county, it occurs in an argillaceous rock, probably belonging at least 20 feet below the top of the Lexington limestone, but its horizon is not definitely known. At Cynthiana, it occurs in the upper part of the quarried rock, also referred to the Paris bed.

One of the most interesting occurrences of *Strophomena vicina* is at Carnestown, in Pendleton county, on the Ohio River, in strata associated with *Eridotrypa mutabilis, Eridotrypa trentonensis, Prasopora falesi, Prasopora simulatrix, Callopora multitabulata, Dalmanella bassleri, Platystrophia colbiensis, Plectambonites sericea,* and *Zygospira recurvirostra.* At Frankfort, *Callopora multitabulata* ranges up as far as the *Strophomena* horizon. *Prasopora simulatrix,* from the Wilmore, gives rise to a closely similar form which reaches the same *Strophomena* horizon, and *Eridotrypa mutabilis* certainly occurs in the lower part of the Paris bed. As far as the present evidence warrants any conclusion, there is no necessity of regarding the *Strophomena vicina* horizon at Carnestown as below the base of the Paris bed.

Thin specimens of *Strophomena,* similar to those at the top of the section described from the vicinity of Flanagan, occur in the upper part of the Paris bed, 2 miles southeast of Brennan Springs, in the northeastern part of Henry county.

Strophomena trentonensis was described by Schuchert from the upper part of the Decorah and the lower part of the Prosser in Minnesota. This is distinctly below the level of the Paris or Bigby bed, in Kentucky. The striae are described as more delicate than those of *Strophomena planumbona-subtenta,* and the oblique wrinkling along the cardinal margin is said to be a more constant feature than in that species. Neither of these statements is true of *Strophomena vicina.* There can be no doubt, however, of the close relationship between these two forms.

No species of *Strophomena* is listed from the Bigby included within the area covered by the Columbia folio, but the *Strophomena* recorded by Schuchert as occurring near the top of the Trenton near Nashville, Tennessee, may be *Strophomena vicina,* rather than *Strophomena trentonensis.* No species of *Strophomena* is known from any part of the Wilmore or Logana (Hermitage of Ulrich).

As far as the origin of *Strophomena vicina* is concerned, it was introduced into central Kentucky during the deposition of the argillaceous limestone 55 feet below the top of the Paris or Bigby bed. This argillaceous horizon is best developed on the western side of the Cincinnati geanticline, in Franklin, Woodford,

and Anderson counties, and here *Strophomena vicina* is most abundant, although it occurs at corresponding horizons also farther eastward. It reappears at the top of the Lexington limestone, in the Cornishville member, in Mercer and Boyle counties. Both the Cornishville member and the underlying Perryville member thin out northeastward, so that their faunas may be regarded as of western or southwestern introduction, as far as this part of the evidence is concerned.

In the Cornishville member, *Strophomena vicina* is associated with numerous specimens of *Dinorthis ulrichi*, and specimens of *Dinorthis ulrichi* occur also locally at the lower *Strophomena vicina* horizon, near the base of the Paris member. Both species probably entered the areas traversed by the Cincinnati geanticline from the same source The nearest relatives of *Dinorthis ulrichi* are *Dinorthis meedsi* and its variety *germana*, from the lower part of the Prosser in Minnesota, Iowa, and Wisconsin. Both in Kentucky and in Minnesota these species are associated with *Hebertella frankfortensis*, a very common species of the Paris and Cornishville members of Kentucky, and of the Bigby of Tennessee. Moreover, in Minnesota, *Strophomena trentonensis*, *Hebertella frankfortensis*, and *Dinorthis meedsi-germana* are associated in the *Nematopora* bed, although *Strophomena trentonensis* is listed chiefly from the *Clitambonites* bed, at the base of the Trenton, and in the immediately underlying part of the Black River group. From these data it may be assumed that *Strophomena vicina*, *Dinorthis ulrichi*, and *Hebertella frankfortensis* entered Minnesota, Kentucky, and Tennessee from the same source and that this source lay west of the Cincinnati geanticline. The apparent absence of any relative of *Strophomena vicina* or of *Dinorthis ulrichi* at corresponding horizons within the area covered by the Columbia folio, suggests a northwestern, rather than southwestern origin for these species, although it is acknowledged that the argument is based upon insufficient data.

Of much more interest is the suggestion that, whatever the origin of *Strophomena vicina*, it probably was different from that of *Strophomena incurvata*. *Strophomena vicina* belongs to the *Strophomena planumbona* type of shell, in which the striations are still fine, although usually coarser than in *Strophomena incurvata*, while the muscular area of the pedicel valve is not flabellate but has the anterior prolongation or gap. This type of shell dis-

appears with the close of the Lexington limestone, and is not seen again until the close of the Arnheim, where it is represented by *Strophomena concordensis*. In the Waynesville and Liberty beds, it is represented by *Strophomena planumbona* and its many varieties; and *Strophomena vetusta*, from the Liberty and Whitewater beds, probably is a variation from the same phylum.

Strophomena higginsportensis, sp. nov.

(*Plate II, Figs. 3 A, B; Plate X, Fig. 4*)

Only the interior of three pedicel valves is known. From these interiors it is evident that the exterior of the pedicel valve is comparatively flat. There is a moderate convexity toward the beak, but anteriorly and laterally the valve is flat rather than concave. The generic relations of the valves is indicated by the muscular area and the hinge-area. In one of the valves from Stony Point, on the Ohio River, in Bracken county, east of Higginsport, the hinge-area has a height of almost 2 mm., the width of the valve being 30 mm. and the length 20 mm. The sides of the delthyrium diverge at an angle of 85 degrees. The deltidium is convex, and the teeth extend scarcely a millimeter beyond the hinge-line. They are supported by flat, vertical, thin dental plates, which extend diagonally forward in the same direction as the sides of the delthyrium, decreasing in height rapidly from the anterior termination of the teeth to a point about 2½ mm. beyond the edge of the hinge-area, defining the posterior parts of the muscular area. From the anterior termination of these dental plates a very low ridge extends forward, limiting the sides of the muscular area. The two ridges are scarcely 3 mm. long; they are slightly convergent toward the front, and at a distance of 5 mm. from the hinge-area, measured vertically, they become imperceptible. The greatest width of the hinge-area is scarcely 6 mm. Anteriorly, the limits of the area are not defined. Excepting in the immediate vicinity of the muscular area, where the shell is smooth, the interior is radiately striated, the shell substance being very thin and plainly indicating the striation on the exterior surface. There are about 15 striae in a width of 5 mm., varying in a second specimen to 19 in a width of 5 mm. A specimen from Ivor, Kentucky, 30 mm. wide and 20 mm. long, presents 12 radiating striae in the same width.

None of these specimens was found in place. The two specimens collected at Stony Point, east of Higginsport, were obtained just above the level of the railroad, among débris regarded at the time of collecting as of lower Eden, or Economy age. The specimen from Ivor, in Pendleton county, was found in the quarry a quarter of a mile east of the railroad station, and evidently had fallen from some ledge exposed in the upper part of the quarry wall. Since both the Winchester or Cynthiana formation, and the lower part of the Eden are exposed here, the exact horizon must remain in doubt.

The danger of founding a new species on the interiors of three ventral valves of a species of *Strophomena* are too obvious to require comment. The possibility of these specimens belonging to the widely spread species of the Eden, *Strophomena hallie,* must be taken into account. Contrasted with the latter species, the following differences are noted. The outline of the shell in *Strophomena hallie* is distinctly more triangular. The brachial valves are strongly convex, and hence the pedicel valve always is distinctly, although not necessarily strongly concave. Compared with the width, the shell is relatively longer. The muscular area is more circular in outline, and is relatively broader. The sides of the delthyrium are more divergent, forming an angle of about 100 degrees. The surface striae are coarser. Usually the specimens of *Strophomena hallie* also are distinctly smaller, equalling about 22 to 25 mm. in width, but one large valve from the lower Eden 1 mile west of Foster, in Bracken county, Kentucky, triangular in form, and referred to this species, measures 37 mm. in width, 27 mm. in length, and has a round muscular area 9 mm. wide.

Strophomena hallie, Miller[3]

(*Plate II, Figs. 1 A, B, C, D, E; 2*)

Strophomena hallie was described by S. A. Miller from Cincinnati, Ohio. The types were found about 150 feet above low water mark on the Ohio River, in an excavation made for Columbia Avenue. This places their horizon in the Southgate or middle Eden bed. The types are preserved in the Faber collection, in the Walker Museum at Chicago University. They are numbered

[3] *Cincinnati Quarterly Journal of Science,* vol. 1, p. 148, 1874.

8848, and form the originals of Figs. 14, 15 and 16, accompanying the original description. These types are illustrated also by Figs. 1 *A*, *B*, *C* on Plate II of this Bulletin

The specific name was given as a compliment to Miss Hallie Cotton, who was the first woman to join the Cincinnati Society of Natural History. This name was changed to *hallana* to Latinize the term, but *halliena* would be better if the term be intended as a compliment to Miss Hallie, and not Miss Hall.

The shell is rather small, and subtriangular in outline. The larger specimens equal 23 mm. in length, 27 mm. in width, and about 7 mm. in convexity. They usually do not exceed 30 mm. in width, but occasionally attain a width of 35 mm. Postero-lateral angles frequently rounded, but usually rectangular, and occasionally even moderately acute.

The brachial valve is slightly flattened posteriorly, the concavity immediately anterior to the beak being almost imperceptible. Usually this flattened area does not extend farther than 5 to 7 mm. from the beak. From this area the shell curves rapidly downward toward the antero-lateral margins, frequently producing long flattened slopes in this direction, resulting in a sub-triangular appearance of the shell. The greatest convexity lies along the median part of the valve, about as far back as the middle of the shell. While the subtriangular outline predominates largely, some specimens occur in which the form is more nearly semicircular. In these the brachial valve is more evenly convex.

Pedicel valve moderately but distinctly convex immediately anterior to the beak, with a reversal of curvature toward the middle. The concavity of the pedicel valve usually is small, resulting in a rather plano-convex shell.

The hinge-area of the pedicel valve has a height of scarcely 2 mm. at the beak, diminishing gradually toward the extremities. Sides of the delthyrium forming an angle of about 100 degrees, and the deltidium is convex, but, judging from the specimens at hand, does not fill up as much of the delthyrium as in other species, the chilidium of the brachial valve being more fully developed. Muscular area approximately circular, bordered posteriorly by the teeth, which project only a short distance beyond the hinge-area. From the anterior margin of the dental plates, low curved ridges extend forward, becoming obsolete immediately in front of the area. A narrow median ridge traverses the muscular

area, and serves as a line of attachment for the adductor muscles. Occasionally a parallel ridge traverses this area, on each side of the median one. These lateral ridges correspond to the posterior terminations of the two inner vascular ridges of other species of *Strophomena*. The remainder of the inner surface of the pedicel valve, outside of the muscular area, appears radiately striated, owing to the thinness of the shell permitting the striation of the exterior surface to be seen.

The lobes of the cardinal process of the brachial valve are narrow and small. The extremities of the crural plates frequently deviate but little from the hinge-line. The adductor scars are not well defined laterally or anteriorly. The median ridge extending forward from the cardinal process frequently is bi-lobed at a point almost on a line with the region where the margin of the adductor scars should be. A parallel ridge occasionally is found on each side of this median one. The remainder of the interior is radiately striated on account of the thinness of the shell.

Radiating striae crossing the exterior surface rather angular, subequal, from 10 to 12 in a width of 5 mm. near the anterior margin of the shell.

Owing to the thinness of the shell, it occurs usually in a fragmentary condition. The fragments rarely are preserved by collectors. The most satisfactory specimens consist of single valves adhering by one of their surfaces to the rock. The vertical range of *Strophomena hallie* needs further study. It probably extends throughout the Eden, but the species is common only at certain horizons in the middle or Southgate division of the Eden.

Strophomena hallie was described from 150 feet above the Ohio River, at Cincinnati, Ohio, from strata evidently belonging near the center of the middle or Southgate member of the Eden, but it is listed by Nickles also from the lower or Economy member. West of Foster, in the northwestern corner of Bracken county, and also opposite Utopia, several miles east of Wellsburg, in Kentucky, *Strophomena hallie* occurs along the railroad at the level of the lower Eden, but it may have slipped down the hill.

Along the railroad, southeast of Maysville, Kentucky, the following section is exposed:

Mount Hope member, with *Amplexopora septosa, Batostoma maysvillensis, Callopora communis, Callopora nodulosa, Constellaria prominens, Escharopora falciformis, Heterotrypa* sp., *Perenopora vera,* and *Strophomena maysvillensis.*

Limestone and clay.. 5 ft. 6 in.

Chiefly clay, with *Dekayella ulrichi* and *Callopora sigillarioides,* belonging to upper or McMicken member of the Eden..........3 ft.

Limestone and clay ....14 ft. 6 in.

Chiefly clay, with *Dekayella ulrichi* ....5 ft. 6 in.

Chiefly clay, with some limestone, containing *Dekayella ulrichi, Callopora onealli,* and, near the middle, also several large specimens of *Platystrophia,* resembling *Pl. ponderosa*.............9 ft. 6 in.

Chiefly clay, with a limestone layer at the top and bottom...........10 ft.

Clay, with *Batostoma implicatum, Ceramoporella milfordensis, Dekayella ulrichi,* and *Perenopora vera*..........................3 ft. 6 in.

Limestone layers, wave-marked at the top...........................2 ft.

Limestone with *Platystrophia,* 1 inch wide, very rare ....4 in.

Clay..3 ft. 6 in.

Chiefly hard limestone.......................................2 ft. 6 in.

Clay ....3 ft.

Wave-marked limestone, with *Strophomena hallie* ....4 in.

Chiefly clay ....4 ft.

Limestone and clay, with *Strophomena hallie* rather common in some of the lower layers. *Constellaria* occurs in one layer near the base. Also, *Batostoma implicatum, Dekayella ulrichi, Perenopora vera,* and *Stigmatella clavis*...................................12 ft.

From the preceding notes it may be seen that *Strophomena hallie* occurs at Maysville between 63 and 80 feet below the top of the Eden. This horizon is regarded as belonging to the upper part of the middle or Southgate member, although it has not been found possible to draw a sharp line between the upper and middle member, diagnostic fossils not having been found.

Strophomena hallie occurs also in the upper part of the tunnel cut, along the railroad, 2 miles northeast of Carlisle, Kentucky. It is common in the Eden in the railroad cut immediately east of the home of George Million, about 4 miles northwest of Richmond, Kentucky. At the latter locality, it occurs only a short distance below the massive Paint Lick or Garrard member, and is associated with a large form of *Platystrophia,* $1\frac{1}{4}$ inches in width, resembling a young quadrate *Platystrophia ponderosa.* Also *Fusispira terebriformis, Amplexopora septosa, Constellaria prominens, Dekayella ulrichi, Escharopora falciformis, Hemiphragma* sp., *Heterotrypa* sp., and *Perenopora vera.* In a general way, this

assemblage of fossils suggests the upper member of the Eden, possibly only the lower part of this member, since a similar *Platystrophia* occurs 35 and 55 feet below the top of the Eden at Maysville. *Strophomena hallie* is found at various localities along the railroad, from the George Million locality westward to beyond the tunnel, 1 mile west of Million Station. At some of these localities it evidently occurs as low as the middle member of the Eden. One of the specimens was remarkably triangular in form (*plate* II, *Fig. 2*). An eighth of a mile west of the tunnel, near the home of Marion Newby, *Strophomena hallie* occurs at the very top of the fossiliferous part of the Eden, at the base of the massive Paint Lick or Garrard member. Near this locality, it occurs also near the base of the Eden section, but not necessarily in rocks equivalent to the lower Eden at Cincinnati, Ohio, since the latter appear to thin out before reaching central Kentucky.

Strophomena hallie occurs near the top of the fossiliferous part of the Eden, just beneath the Paint Lick massive rock, about 1 mile east of the Dix River, along the road from Lancaster to Danville; also 1½ miles west of Bestonia, in the southwestern part of Mercer county. This may be the horizon also of *Strophomena hallie*, in the northern corner of Lincoln county, north of the cross road marked Hubble on the U. S. Geological Survey map. Faulting immediately south of the exposure introduces an element of uncertainty.

Strophomena hallie occurs about half-way between the top and the bottom of the Eden, along the railroad from Hatton to Consolation, in the first cut east of the home of Tom Woods, in the eastern part of Shelby county. Since the lower Eden thins out in this direction, the horizon undoubtedly is middle Eden.

Strophomena hallie occurs also in the Rogers Gap division of the Eden at Sadieville, in the northern half of Scott county, associated with *Cryptolithus tessellatus* (*Trinucleus concentricus*), *Eridorthis nicklesi*, *Hebertella* sp., and *Clitambonites rogersensis*. At the base of this division, at Rogers Gap, *Crepipora venusta* and *Heteropora foerstei* also occur. This fauna, which is the basal fauna of the Eden in central Kentucky, shows, as a whole, numerous features not seen in any part of the Eden at Cincinnati, Ohio. It appears, however, to be represented there at least in part, since *Eridorthis* occurs occasionally at the base of the Eden at Brent, also 1 mile west of Eight Mile Creek, and at Ivor, still

farther up the Ohio River. On the other hand, the typical lower Eden seems to disappear southward before reaching Scott county. As a matter of fact, similar faunal changes are noted in tracing the Fairmount fauna from Cincinnati southward. Possibly the simplest explanation would be that quite dissimilar faunas existed practically contemporaneously in different parts of the Cincinnatian areas at different times.

Directly north of Blanchet, in the southern part of Grant county, a species of *Strophomena* occurs, associated with *Amplexopora septosa, Callopora nodulosa, Coeloclema alternatum, Constellaria plana,* and *Heterotrypa* sp. Since *Heterotrypa* occurs also at the top of the fossiliferous part of the Eden beds, just beneath the Paint Lick or Garrard division, at the George Million locality, west of Richmond, the chief reason for regarding the exposures north of Blanchet as Mount Hope is the absence of *Dekayella ulrichi,* although it is regarded as very low in the Mount Hope, probably at its base.

Possibly *Strophomena hallie* is the ancestral form of *Strophomena maysvillensis.*

At Vevay, in Indiana, the upper Eden, containing *Amplexopora septosa,* and *Dekayella ulrichi-robusta,* is estimated at 58 feet in thickness. *Strophomena hallie* occurs 16 feet below the top of the middle Eden, and also at various horizons between 40 and 58 feet below the top of this division. *Aspidopora newberryi* occurs 60 feet below; *Monotrypa turbinata,* 65 feet below, and *Stigmatella nana,* 68 feet below the top of the middle or Southgate division of the Eden. These bryozoans are regarded as lower Eden, usually. This gives such a great thickness of lower Eden as far west as Vevay that it is difficult to believe that the lower Eden practically has disappeared at Sparta, in the southwestern corner of Gallatin county, Kentucky, unless the bryozoans mentioned have a greater vertical range than supposed hitherto.

Aspidopora newberryi, Callopora onealli, and *Crepipora venusta* occur on the river bank, a quarter of a mile west of Markland, about 3 miles east of Vevay, at the base of the Eden section. *Strophomena hallie* was collected also about 60 feet above the base of the Eden, 8 miles east of Vevay, opposite Warsaw.

At the junction of Mud Lick and South Fork, half a mile south of Milton, in Ohio county, Indiana, *Strophomena hallie* occurs about 85 feet below the top of the Eden, in the upper part of the middle

or Southgate division of the Eden, associated with *Batostoma jamesi, Callopora nodulosa, Coeloclema alternatum,* and *Dekayella ulrichi.*

Strophomena hallie is known at present only from the Eden of Kentucky, Ohio, and Indiana. If the Eden be correlated with the Frankfort shales of New York and the Sevier shale of the southern Appalachians, then the absence of any representatives of *Strophomena hallie* in these strata is significant. In the equivalent strata along the northern parts of Lake Huron and thence along the southern shore of Georgian Bay to the vicinity of Toronto, no species of *Strophomena* is known. The Eden is entirely absent in the northern part of the Mississippi Valley. From these data it seems probable that *Strophomena hallie* is a species of southern origin. This conclusion is favored also by the much greater abundance of *Strophomena hallie* in central Kentucky, and thence eastward as far as Maysville, than farther northward and northwestward, in Ohio, Indiana, and the northwestern exposures of Kentucky. A similar conclusion might be reached also from the presence of *Strophomena hallie* in the southern fauna at the base of the Eden section as exposed in central Kentucky. This southern fauna includes *Eridorthis nicklesi, Clitambonites rogersensis, Heteropora foerstei,* a species of *Hebertella,* and other species not known in the contemporaneous strata farther northward, or but rarely found there. These lower strata, forming the Rogers Gap division of the Eden, present an assemblage of species so different from the lower or Economy member of the Eden that there is a tendency to classify them with the middle Eden. They appear, however, to indicate rather how far northward the southern type of Eden had progressed locally during the deposition of the earlier part of the Eden.

Strophomena hallie belongs to the group of shells characterized by a weak delimitation of the muscular area of the pedicel valve, especially anteriorly. This area is not flabellate, nor is it extended anteriorly into a gap; its general form is roundish. The radiating striae, although not coarse, tend to be coarser than those of the *Strophomena planumbona* type of shells. *Strophomena hallie* is regarded as a precursor of *Strophomena maysvillensis,* a much more coarsely plicated species, ranging from the base of the Mount Hope to the upper parts of the Fairmount members of the Maysville.

Strophomena millionensis, sp. nov.

(*Plate I, Figs. 9 A, B, C; Plate X, Fig. 14*)

About 1 mile west of Million, in Madison county, Kentucky, the railroad passes through a tunnel. An eighth of a mile west of the tunnel, at the Marion Newby locality, the base of the Eden is exposed 10 feet above the railroad. A short distance west of this locality, the base of the Eden contains, in addition to numerous specimens of *Plectambonites sericea*, a few of *Dalmanella multisecta*, and an occasional specimen of the trilobite familiarly known as *Trinucleus concentricus*, also a small species of *Strophomena*. The largest specimen of this species, found so far, has a width of 19 mm. and a length of 13.5 mm. The relation of length to width, however, varies, being in most specimens about 14 to 17. The outline of the shell is subquadratic, the postero-lateral angles being rectangular, or between 80 and 90 degrees, with a tendency toward rounding at the tip of the angle in some specimens.

The brachial valve is flattened posteriorly, this flattening extending forward for about half the length of the shell, beyond which the sides of the shell slope toward the antero-lateral margins, producing a low, broad, median elevation anteriorly, whose crest makes a moderate angle with the flattened posterior part of the valve.

The hinge-area of the pedicel valve has a height of about 1 mm. at the beak; it forms an angle of about 125 to 130 degrees with the general plane of the shell. The sides of the delthyrium form an angle of 80 degrees, and the deltidium is evenly convex. The posterior half of the valve is gently convex, with a variable amount of flattening toward the postero-lateral margin. The anterior half is characterized by a broad and shallow median depression or sinus, corresponding to the median fold on the opposite valve. At the anterior margin of this fold and sinus the shell frequently is slightly produced, resulting in a slightly triangular, rather than evenly convex outline.

The radiating striae are rather coarse. Usually about 5 striae occupy a width of 2 mm., but on some parts of some shells the number may be as low as 4, or as high as 6 in the same width.

The general appearance of the shell closely resembles that of *Strophomena sulcata*. The chief difference appears to be that in *Strophomena millionensis* the spaces between the radiating striae

usually are wider, and, in most of the specimens, the relative width, compared with the length, is less.

Owing to the presence of these shells in the lower part of the Eden formation, the question arises whether the forms under discussion might be depauperate specimens of *Strophomena hallie.* It is then noted that, while the coarseness of the striae is about the same, there is an important difference shown by the pedicel valve. In *Strophomena hallie*, the pedicel valve is concave except in the immediate vicinity of the beak. In *Strophomena millionensis*, however, the shell is elevated from the umbo anterior to the beak as far as the antero-lateral margins, resulting in two divergent areas of elevation bordering the very broad and shallow median depression already described.

Some of the specimens of *Strophomena scofieldi*, from the base of the Trenton of Minnesota, present a low median fold on the brachial valve and a corresponding very shallow sinus on the pedicel valve; however, judging from a set of specimens kindly sent me by Prof. F. W. Sardeson, the majority of specimens do not show the sulcation, the latter not being in any strict sense characteristic of the species. The specimens attain a width of about 20 mm. The pedicel valves are flattish, except near the beak. The brachial valves are moderately convex, though slightly flattened at the beak. The number of radiating striae is about 8 in a width of 2 mm.

It is not certain that *Strophomena millionensis* is the precursor of *Strophomena sulcata*, or of any of the later species having this form of shell. Specimens having this form may not have constituted a distinct phylum within the genus *Strophomena*, but may have originated separately, at different times, from species of the ordinary form. Thus, *Strophomena sinuata* may have originated from *Strophomena maysvillensis*, and *Strophomena millionensis* may have originated from the same species which gave rise to *Strophomena hallie.* The sulcate forms of *Strophomena scofieldi* evidently originated from the ordinary, not sulcated forms of this species. From what species, however, could *Strophomena sulcata* have had its origin, if not from *Strophomena sinuata?*

Strophomena maysvillensis, Foerste[4]

(*Plate II, Figs. 4 A, B, C, D, E, F, G, H, I, J*)

Strophomena maysvillensis is closely related to *Strophomena planoconvexa*. On the average, however, it is a larger and longer species, and the outline frequently is subtriangular, owing to the downward deflection of the antero-lateral parts of the brachial valve. The sides of the shell frequently converge posteriorly, the hinge-line being shorter than the width of the shell across the middle. Sometimes the sides meet the hinge-line at right angles, and occasionally even at the slightly acute angle of about 80 degrees. The pedicel valve is only moderately concave toward the middle, or even is almost flat, but the brachial valve frequently is rather strongly convex, especially in the more triangular specimens. In the broader, less triangular forms, the convexity usually is not conspicuously greater than that of typical specimens of *Strophomena planoconvexa*. The flattening of the brachial valve anterior to the beak is nearly obsolete. The ratio of the length of the shell to the length of the hinge-line averages between 0.84 and 0.87, but may be as low as 0 70, or as high as 1.00; the ratio of the convexity of the shell to the length frequently equals 0.40, but shells of less convexity are common. Hinge-area high, forming an angle of about 45 degrees with the plane of the pedicel valve.

The deeply impressed muscular area of the pedicel valve is nearly circular in form, bordered on each side by a strongly elevated, sharp, curved ridge, deflected slightly forward at the gap at the anterior margin of the area. The interior of the pedicel valve is thickened a short distance within the anterior and lateral margins of the shell. The marginal part of the valve, exterior to the thickened part, frequently has a width of 2 mm. anteriorly, the distance across the thickened area being 4 or 5 mm. at the median parts of the shell. This thickened area or border is crossed by vascular grooves and ridges, and the median part is connected with the anterior gap of the muscular area by rather indistinct median grooves and ridges.

The posterior outlines of the adductor areas of the brachial valve are distinctly defined by the callosity beneath the cardinal

[4] *Denison Univ. Bull.*, vol. xiv, p. 212, 1909.

process, and the anterior extremities of the crural plates. The latter curve rather strongly forward. A low median ridge extends forward from the cardinal process, between the adductor areas. Anterior to a line connecting the anterior margins of the adductor areas, there frequently is a median depression, bounded laterally by the inner pair of vascular ridges which are parallel to the median parts of the shell. The narrow posterior extension of this inner pair frequently may be distinguished from the median ridge which extends forward from the cardinal process. The outer pair of vascular ridges is low, broad, and rather indistinct, terminating posteriorly at the anterior margin of the adductor areas.

The radiating striae on the exterior surface are rather coarse, agreeing in this respect with those of *Strophomena planoconvexa*. On the pedicel valve, 10 to 12 striae occur in a width of 5 mm. about 25 mm. from the beak. The same number of striae occur on many of the brachial valves, but here sometimes 14 and 15 striae are found in the same width. Frequently the striae appear coarser along the middle and posterior parts of the shell, becoming finer and less conspicuous along the anterior margin of the shell.

In the younger stages of growth, the postero-lateral angles of the shell are more nearly rectangular. In adult specimens these angles often are more or less rounded, and the posterior part of the lateral outlines converges slightly toward the hinge-line.

The type specimens of *Strophomena maysvillensis* were found in the lower part of the Fairmount bed, along the railroad, 2 miles southeast of Maysville, Kentucky.

At Maysville, in Mason county, Kentucky, the base of the Fairmount is placed at the base of the strata in which *Strophomena maysvillensis* is most abundant. This part of the section is 18½ feet thick. It consists, near the base, of fairly massive limestone, weathering, toward the top, to shaly limestone interbedded with more solid layers. The overlying argillaceous rock section, about 50 feet thick, is nearly unfossiliferous, and is correlated with the Tate layer, typically exposed in Madison county. Beneath the Fairmount, *Strophomena maysvillensis* is found in small numbers down for a vertical distance of 22 feet, in strata regarded as corresponding to the Mount Hope member, typically exposed at Cincinnati.

A similar distribution of *Strophomena maysvillensis* in the Mount Hope and Fairmount members has been noted as far south as

Madison county, and thence westward. Along the southwestern line of Madison county, about 1 mile north of Paint Lick, the following section is exposed.

Base of Tate layer.
Argillaceous limestone with *Platystrophia ponderosa*...............4 ft.
Unfossiliferous argillaceous shale...............................8 ft.
Shaly limestone with *Orthorhynchula linneyi* and *Platystrophia ponderosa* common ....24 ft.
Limestone and limestone rubble with *Platystrophia ponderosa*..15 ft. 6 in.
Strophomena maysvillensis at top, middle, and base of section, but not common...9 ft.
Interval...6 ft.
Strophomena planoconvexa rare.
Interval ....7 ft. 6 in.
Strophomena maysvillensis very abundant........................2 ft.
Base of Fairmount.
Argillaceous limestones interbedded with clay. *Strophomena maysvillensis* common on the upper surfaces of many of the limestone layers, but not as abundant as at the base of the Fairmount.......28 ft.
Brachiospongia laevis.
Argillaceous limestone with *Strophomena maysvillensis*, forming the base of the Mount Hope................................2 ft. 6 in.
Cross-bedded, argillaceous limestone, forming the top of the massive argillaceous rock section which may be called the Paint Lick division of the Garrard. About 6½ feet below the top of this section *Strophomena maysvillensis* makes its first appearance. The total thickness of the Paint Lick division is about..........60 ft.

In the preceding section, the occurrence of *Strophomena maysvillensis* in the upper part of the Paint Lick section should be especially noted.

Along the railroad, about 2 miles northwest of Richmond, the Tate layer has a thickness of about 30 feet. Most of it is thin-bedded or shaly. The following section is exposed.

Base of Tate layer.
Orthorhynchula linneyi very abundant.......................5 ft. 6 in.
Orthorhynchula linneyi associated with *Platystrophia ponderosa* .5 ft. 6 in.
Rough argillaceous limestone with *Platystrophia ponderosa*....5 ft. 6 in.
Interval...5 ft. 6 in.
Escharopora hilli and *Strophomena planoconvexa*.............5 ft. 6 in.
Strophomena maysvillensis in moderate numbers near top and resembling *Strophomena planoconvexa*. Typical forms of *Strophomena maysvillensis* near the base......................................22 ft.
Mount Hope member, with *Strophomena maysvillensis* only in moderate numbers.

Orthorhynchula linneyi has not been traced northward beyond Madison county. From Madison county southward, as far as the middle of Lincoln county, it occupies a definite horizon, a short distance below the base of the Tate layer. Usually the highest level for *Strophomena maysvillensis* is below the *Orthorhynchula* horizon. However, at Givens Station, 3 miles east of Shelby City, and at the bridge 1 mile west of Lincoln county, *Orthorhynchula* occurs, associated with *Strophomena maysvillensis* at the highest levels occupied by the latter.

Along the railroad from Consolation to Benson, in the eastern part of Shelby county, the following section is exposed:

Depot at Consolation.
Interval ....18 ft.
Platystrophia ponderosa not common, rare below............12 ft. 6 in.
Strophomena planoconvexa at top and bottom......................4 ft.
Interval ....4 ft.
Strophomena planoconvexa, Strophomena sinuata and *Plectorthis neglecta* ....4 ft.
Limestone with *Strophomena planoconvexa*.......................7 ft.
Lowest *Platystrophia ponderosa*.
Clay..2 ft.
Abundantly fossiliferous shelly limestone........................18 ft.
Strophomena planoconvexa at top and bottom.....................2 ft.
Interval ....6 ft.
Strophomena maysvillensis common in rough limestone.
Dalmanella not common. ....8 ft.
Strophomena maysvillensis not rare..............................3 ft.
Base of Fairmount.
Limestone with *Dalmanella multisecta* and *Strophomena maysvillensis* at top. Lowest horizon for *Strophomena maysvillensis* occurs at base of this section...29 ft.

The occurrence of *Strophomena maysvillensis* in the Mount Hope, as well as in the Fairmount, may be noted also along the pike from Shelbyville to Clay City. Northward, the number of specimens in the Mount Hope member diminishes rapidly. The following section is exposed near Port Royal, over 5 miles east of Turner Station, in the northeastern corner of Henry county.

Level of streets at Port Royal.
Interval with *Platystrophia ponderosa* at the base..................40 ft.
Platystrophia ponderosa abundant, *Monticulipora molesta* at the top..10 ft.
Interval..23 ft.

Sandy-appearing limestone..5 ft.
Platystrophia ponderosa moderately abundant except toward base....23 ft.
Strophomena maysvillensis rather common..........................1 ft.
Limestone with *Strophomena maysvillensis* not common............19 ft.
Limestone with some thin sandy-appearing layers..................15 ft.
Rough limestone full of *Strophomena maysvillensis*..................9 ft.
Base of Fairmount.
Exposures poor, with *Strophomena maysvillensis, Platystrophia profundosulcata-hopensis*, a few specimens of *Dalmanella multisecta, Constellaria florida, Callopora nodulosa*..........................11 ft.
Top of zone with *Dalmanella multisecta* abundant.

North of the Ohio River, in Indiana, *Strophomena planoconvexa* and its relative *Strophomena maysvillensis* occur in much smaller numbers and are restricted in their vertical range chiefly to two horizons, separated by a considerable interval in which no representatives of these species are known.

Similar features are presented at Williamstown, in Grant county, Kentucky. Here, along the railroad north of the town, *Strophomena planoconvexa* occurs at two horizons separated by an interval of 6 feet, and *Strophomena maysvillensis* is found about 30 or 35 feet lower, being abundant in a section about 7½ feet thick. The *Strophomena planoconvexa* horizon unquestionably is of Fairmount age. It contains *Atactoporella* sp., *Callopora* sp., *Constellaria florida, Constellaria plana, Dekayia aspera, Heterotrypa* sp., *Homotrypa curvata*, and *Perenopora* sp.

At the *Strophomena maysvillensis* horizon, *Amplexopora septosa, Callopora nodulosa, Dekayella ulrichi*, and *Heterotrypa* sp. were collected. These suggest the base of the Mount Hope horizon, *Dekayella ulrichi* being regarded as limited to the Eden beds.

Strophomena occurs near the base of the Mount Hope and at the base of the Fairmount bed also in southern Indiana.

An eighth of a mile west of Brooksburg, in the southeastern part of Jefferson county, Indiana, *Strophomena* occurs 7½ feet above the horizon at which *Dalmanella multisecta* is very common. At Vevay, in the southern part of Switzerland county, the top of the Eden contains *Dekayella ulrichi*, associated with very abundant specimens of *Dalmanella multisecta*. In the immediately overlying layers, *Platystrophia profundosulcata-hopensis* occurs. *Strophomena* ranges from 2 to 12 feet above the base of the Maysville. At several levels within the same range, *Plectorthis neglecta*

occurs. This part of the section forms the lower part of the Mount Hope bed.

Plectorthis neglecta is characteristic of the Mount Hope. It may be traced southward as far as Blanchet, in the southern part of Grant county, Kentucky, and eastward as far as Georgetown, in Brown county, Ohio. Wherever *Strophomena* occurs a short distance below the *Plectorthis neglecta* horizon, it may be regarded as belonging to the lower part of the Mount Hope, although, as a matter of fact, the Mount Hope is better defined by the occurrence at a lower level, of the presence of *Dekayella ulrichi*, which ranges to the very top of the Eden, and the introduction, immediately above the *Dekayella ulrichi* zone, at the very base of the Mount Hope, of a rich bryozoan fauna, which is very characteristic of this horizon in southern Indiana, and which will serve as a more ready guide than *Plectorthis neglecta*, which is not always present.

The interval between the base of the Mount Hope and the Bellevue member, in southern Indiana, varies from 85 to 105 feet, as far as may be determined from a number of sections made where the exposures were clear, but the gradients along which it was necessary to make the measurements were long. At this Bellevue horizon, in Indiana, *Platystrophia ponderosa* is very abundant, while specimens of this species are far from common in the immediately underlying Fairmount strata.

A second horizon for *Strophomena* occurs between 30 and 40 feet below the abundant *Platystrophia ponderosa* horizon, or between 50 and 60 feet above the lower *Strophomena* horizon, which is found at the base of the Mount Hope. Both the upper and lower horizon with *Strophomena* are exposed 2 miles south of Jacksonville, on the Plum Creek road, about 3½ miles north of Vevay; in the northeastern corner of section 25; also 7½ miles northeast of Vevay, or 4 miles east of Jacksonville, in the southwestern corner of section 14, near the home of J. W. Evett, in Switzerland county; and a quarter of a mile northwest of Guilford, northwest of the home of George Friedenberg, in Dearborn county. The upper *Strophomena* horizon is exposed also half a mile northwest of Dillsboro Station, 40 feet below the *Platystrophia ponderosa* horizon, in Dearborn county, where the railroad is crossed by a road leading northward to Chesterville; and along

the upper part of the road ascending the hill east of Scott Chapel, along the eastern branch of Lock Lick Creek, 2 miles east of the J. W. Evett locality, or 3 miles north of Florence, in Switzerland county. At the latter locality the upper *Strophomena* horizon is underlaid by thin-bedded, argillaceous, sandy, brown shale, and this thin-bedded shaly material occurs at many localities in the same county at the same horizon, apparently the upper half of the Mount Hope bed.

At the lower horizon, in Indiana, the specimens of *Strophomena* are small, they have a more convex brachial valve and are regarded as more closely allied to *Strophomena maysvillensis*. At the upper horizon, the specimens of *Strophomena* are larger and flatter, and are regarded as *Strophomena planoconvexa*.

At most places, in Ohio, *Strophomena* occurs chiefly at the base of the Fairmount member, and, in fact, *Strophomena planoconvexa* was used by Mr. John M. Nickles to mark the plane between the Mount Hope and the Fairmount. Occasionally, however, *Strophomena* occurs also here at two horizons. For instance, at Allandale, 10 miles northeast of the center of Cincinnati, *Strophomena planoconvexa* occurs at the base of the Fairmount, while at a road crossing the railroad half a mile eastward, *Strophomena maysvillensis* occurs at a lower level in the Mount Hope.

Strophomena maysvillensis occurs in considerable numbers also along the Cumberland River, from the northwestern corner of Wayne county to the northeastern part of Cumberland county. Here it is associated with *Orthorhynchula linneyi*, *Escharopora hilli*, and *Cyrtoceras vallandinghami*, all indicating the top of the Fairmount as exposed in central Kentucky. *Strophomena maysvillensis*, associated with *Orthorhynchula linneyi*, is found also in Tennessee, occurring as far south as the area covered by the Columbia folio.

Strophomena maysvillensis is known at present from Tennessee, Kentucky, Ohio, and Indiana. In Kentucky, it is most abundant and of largest size in the central part of the state and thence northeastward as far as Maysville. Moreover, in this part of the state it begins its range as low as the base of the Mount Hope, while northward and northwestward it is rare or absent until the top of the Mount Hope is reached. These facts suggest the derivation of *Strophomena maysvillensis* from some southern source. It may be

said to characterize the Maury phase of the Fairmount, as exposed typically in Maury county, Tennessee, in southern Kentucky, along the Cumberland River, and in central and east-central Kentucky.

It is difficult at times to determine whether the purposes of science will be served best by emphasizing the close relationship of different forms and by grouping them all under the same specific name, or by emphasizing their differences to the extent of assigning them even to different species. The present is such a case. *Strophomena maysvillensis* is closely related to *Strophomena planoconvexa.* Though occurring at different horizons, locally, they occasionally are associated, and apparently are connected by intermediate forms It is unfortunate that Hall's types of *Strophomena planoconvexa* were chosen from the smaller, flatter, and more quadrate forms, especially if *Strophomena maysvillensis,* of much more extended vertical and horizontal range, is to be regarded as merely the more vigorous form of *Strophomena planoconvexa.*

Strophomena planoconvexa, Hall[5]

(*Plate I, Figs. 1 A, B, C, D, E, F; 2 A, B*)

The type specimens of *Strophomena planoconvexa,* preserved in the American Museum of Natural History, in New York City, and numbered 919-2, are labelled as coming from Cincinnati, Ohio. They are small individuals, the larger one about 25 mm. in width, and belong to a form not rare at a very limited vertical range at the base of the Fairmount bed. At the same horizon, in Kentucky, half a mile north of Crescent Springs Station, on the Queen and Crescent Railroad, south of Cincinnati, an individual was found, 39 mm. wide, 28 mm. long, and 8.5 mm. in convexity.

This species is remarkable for the slight concavity of the pedicel valve. It is evident that the valve in its earlier stages of growth was slightly convex, especially near the beak, and had attained a length of 11 to 14 mm. before reversing its curvature. This concavity frequently does not exceed 1 mm. in specimens 35 mm. wide.

The brachial valve usually is only moderately convex. This convexity frequently does not exceed 6 mm. in specimens 33 mm.

[5] *New York Paleontology,* vol. i, p. 114, 1847.

wide, but may equal 9 mm. in the same width. The ratio of the length of the shell to the width usually varies between 0.70 and 0.80.

The muscular area of the pedicel valve is shallow, but the curved lateral border is distinct, especially along the exterior edge. Anteriorly, this lateral border is deflected slightly forward, producing a median gap. The median ridge traversing the muscular area is low and rather narrow anteriorly. There are only faint traces of median vascular markings or of any thickening of the shell toward the anterior margin. The interior surface, in general, is smooth.

In addition to the cardinal process, the crural plates, and the low median elevation, the interior of the brachial valve may show the posterior part of the inner pair of the vascular ridges frequently found in species of *Strophomena.*

The radiating striae are much coarser than in most species of *Strophomena.* This coarseness is especially noticeable over the middle regions of the shell, and even toward the beak, where the radiating striae usually are comparatively fine. About 7 to 9 striae occupy a width of 5 mm. near the margin of the brachial valve, while 7 to 10 occur in the same width on the pedicel valve.

The type specimens of *Strophomena planoconvexa* were found at Cincinnati, Ohio, and here they occur at the base of the Fairmount bed. They are found at this horizon as far north as the clay banks on the West Fork of Mill Creek, southwest of Glendale; 1 mile east of Reading; and at Allandale, 3½ miles northeast of Madisonville, in Hamilton county. Also, northeast of Crescent Springs, along the railroad, in Kenton county, Kentucky; and nearly 2 miles west of Verona, in the southern part of Boone county. The upper horizon of *Strophomena* along the railroad north of Williamstown, in Grant county, Kentucky, consists of *Strophomena planoconvexa* at the base of the Fairmount, and this horizon, with the same form of *Strophomena,* may be traced as far south as Mason. The upper horizon for *Strophomena,* from Guilford, in Dearborn county, to the vicinity of Vevay, in Switzerland county, in Indiana, is approximately at the same horizon, the base of the Fairmount, and contains the same species, *Strophomena planoconvexa.*

Along the railroad from Consolation to Benson, in the eastern part of Shelby county, Kentucky, the specimens of *Strophomena* in the Mount Hope and in the lower part of the Fairmount section,

11 feet thick, are identified as *Strophomena maysvillensis,* while the specimens in the overlying part of the Fairmount, 47 feet thick according to measurements taken along a long gradient, are more like the typical specimens of *Strophomena planoconvexa*.

Somewhat similar phenomena are noted in Madison county, Kentucky. Here the specimens of *Strophomena* which occur in the upper part of the Fairmount, beneath the Tate layer, more closely resemble *Strophomena planoconvexa,* while those in the lower half of the Fairmount, and in the Mount Hope bed, are identified as *Strophomena maysvillensis.* These features are well presented by the section along the railroad, several miles west of Richmond, and also by the road leading west from the Richmond pike, 1 mile north of Paint Lick.

Strophomena occurs in quite considerable numbers, associated with *Orthorhynchula linneyi,* along the Cumberland River, from the northwestern edge of Wayne to the northeastern part of Cumberland county. Some of the specimens have the flat, more quadrate form characteristic of the type specimens of *Strophomena planoconvexa.* Others have the more triangular form, characteristic of *Strophomena maysvillensis.*

At the time when the specific name *Strophomena maysvillensis* was proposed, it seemed possible to distinguish two species, one of which was smaller, flatter, and more quadrate in outline, while the other was a larger and more triangular form, more strongly arched across the middle. The fact that in some parts of the field, the flatter, more quadrate form occurred at a higher horizon, rather favored this view, even if this separation by horizons could not be maintained when tracing these fossils to other areas. However, more recently, the conviction has grown that the larger, more triangular form is likely to be present wherever conditions strongly favored the development of the species, so that the specimens grew larger, developed more vigorous shells, and became very numerous. On the contrary, where conditions were less favorable, the specimens were smaller, the valves were thinner, and flatter, and the outline approached more nearly the ordinary quadrate form.

From this point of view, *Strophomena maysvillensis* may be regarded as simply a more healthy form of *Strophomena planoconvexa,* the type specimens of the latter having been collected so far north of the area in which the growth of the species was most vigorous, that only the more depauperate specimens were found.

In a similar manner, the flatter, more quadrate forms occur in central Kentucky, chiefly in the upper part of the Fairmount, especially where the number of specimens is small, and the species evidently is disappearing.

Regarding *Strophomena maysvillensis* as only the more vigorous form of *Strophomena planoconvexa*, the distribution of the former should be added to that of the latter, in order to secure a complete account of the geographical and vertical distribution of *Strophomena planoconvexa.*

Strophomena sinuata, Meek[6]

(Plate I, Figs. 3 A, B, C)

Strophomena sinuata was described by Meek, probably from material supplied by U. P James. In the James collection, in the Walker Museum at Chicago University, there are several entire specimens, numbered 56, and labelled as types of *Strophomena sinuata*, among which none of the specimens figured by Meek (*Ohio Paleontology*, vol. i, plate 5, Figs. 5, *a–d*) could be identified. They probably are a part of the series from which Meek secured his material. Similar statements may be made of most of the other Cincinnatian specimens figured by Meek, unless the specimens were very rare and were returned to some private collection.

Compared with *Strophomena sulcata*, the shells of *Strophomena sinuata* are somewhat larger, frequently equalling 25 mm. and sometimes attaining 30 mm. in width. The general outline is about the same, and usually there is no great difference in the amount of sinuosity of the valves anteriorly, although comparatively deep and narrow sinuses are not uncommon in *Strophomena sulcata*, and are comparatively rare in *Strophomena sinuata*. The chief difference consists in the coarseness of the radiating striae. Of these there are about 6 to 7 within a width of 5 mm. near the anterior margin, or 36 to 40 within 1 cm. of the beak, occasionally equalling 42 or even 45. Usually the brachial valve appears more convex from front to rear; this is due partly to the fact that the median elevation curves downward below the general plane of the flattened area which is located anterior to

[6] *Ohio Paleontology*, vol. i, p. 87, 1873.

the beak; partly it is due also to the greater convexity of the sides of the valve, anterior to the postero-lateral angles. The umbonal part of the pedicel valve, anterior to the beak, appears less elevated, and the general appearance of the posterior half of the valve is somewhat flatter.

The interior of the valves is very similar to that of *Strophomena sulcata.* It is strongly striated radially, owing to the thinness of the shell. The muscular area of the pedicel valve is circular, it is well outlined laterally but not anteriorly. The two-lobed cardinal process, the divergent crural plates, and the median ridge, extending forward from the callosity immediately anterior to the cardinal process, are well developed on the interior of the brachial valve. The diductor area is poorly defined.

Strophomena sinuata was described from the upper part of the Fairmount, at Cincinnati, Ohio, at a horizon which is a considerable distance above the *Strophomena planoconvexa* level, at the base of the Fairmount. It occurs also at Madisonville, Ohio. At Bald Hill, 1 mile west of Georgetown, in Brown county, Ohio, *Strophomena sinuata* is not rare at a horizon 45 feet above that part of the section, 6½ feet thick, in which *Strophomena maysvillensis* is common. A few specimens of *Strophomena planoconvexa* occur both above and below this *Strophomena sinuata* horizon for a distance of 10 feet. At Bald Hill, the specimens of *Strophomena sinuata* have an appearance as though they might have been derived from some nasute form of *Strophomena maysvillensis;* in other words, as though they might be depauperate specimens of the latter. *Strophomena sinuata* occurs also as an occasional loose specimen west of Mount Sterling, 3 miles north of Vevay, in Switzerland county, in Indiana. A single specimen, resembling *Strophomena sinuata,* was found 50 feet above the base of the section in which *Strophomena maysvillensis* is very common, and which here is regarded as at the base of the Fairmount.

Strophomena sinuata, although resembling *Strophomena millionensis,* certainly was not derived from that species. It has been found so far only near the upper limits of the range of *Strophomena maysvillensis.* In Ohio and Indiana it is known only near the northern limits of the geographical range of that species. It is also listed by Ulrich from the *Strophomena maysvillensis* horizon in the Maury phase of the Fairmount, within the limits of the Columbia folio, in Tennessee. I have never seen any very typical

specimens in Kentucky. The species, owing to its associations, is regarded as of southern origin. This is to be expected, if it is a derivation from *Strophomena maysvillensis.*

Strophomena concordensis, Foerste[7]

(*Plate III, Figs. 1 A, B, C, D, E, F, G, H, I, J, K, L, M, N*)

Strophomena concordensis evidently is closely related to *Strophomena nutans,* but it is a much larger species than the typical form of the latter. Specimens frequently attain a width of 42 mm., a length of 30 mm., and a convexity varying from 11 to 15 mm. The convexity of the more strongly arched specimens varies between 0.44 and 0.48, although frequently less. In *Strophomena wisconsinensis* this ratio may equal 0.55, or even 0.60. The lateral outlines, posterior to the middle of the shell, frequently are subparallel or only moderately divergent, as in *Strophomena nutans,* but more frequently the outline of the shell is subtriangular, the postero-lateral angles varying from 75 to 55 degrees. In *Strophomena nutans,* the outlines more commonly are subpentagonal, and shells having a subtriangular outline are far less common. The subtriangular appearance of the brachial valve is strengthened by the downward deflection of the antero-lateral parts of the valve. The posterior part, within 10 mm. of the hinge-line, usually is distinctly flattened, but the concavity of the valve immediately anterior to the beak is almost imperceptible. The convexity of the umbonal parts of the pedicel valve, immediately anterior to the beak, is moderate, but is much more readily perceptible than the corresponding almost imperceptible umbonal concavity of the brachial valve. The concavity of the middle part of the pedicel valve varies, of course, with the general convexity of the brachial valve. In extreme cases it is deeply concave, the maximum concavity being at or immediately anterior to the middle of the shell. Oblique wrinkling of the shell along the hinge-line may be detected occasionally.

The radiating striae of the brachial valve are very fine near the beak, but become coarser toward the anterior margin of the shell. Frequently every third, fourth, or sixth striation is more prominent, especially anteriorly, but in some specimens they alternate in

[7] *Denison Univ. Bull.,* vol. xiv, p. 213, 1909.

size or are approximately equal toward the anterior margin; or they may be very nearly equal in size even posteriorly. About 25 mm. from the beak they usually vary between 12 and 16 in a width of 5 mm., but occasionally this number is increased to 18, 20, and even 24. The radiating striations of the pedicel valve are about equal to those of the brachial valve posteriorly, but anteriorly they are more numerous, frequently equalling from 20 to 24 in a width of 5 mm., although occasionally as low as 17, and even 14. When every fourth striation is conspicuously stronger than the intervening ones, their number usually equals about 6 in a width of 5 mm.

Aside from the larger size of the shell, the interior of the pedicel valve presents the most characteristic diagnostic features of this species. The thickened border along the anterior and lateral margins of the valve is never as prominent and abrupt, nor as well defined along the inner edge as in the case of *Strophomena nutans*. The absence of the strong vertical thickening along the median anterior nasute edge of the pedicel valve, and of the strong vascular markings on the upper and inner side of this thickening, is especially characteristic. Usually, the thickening along the anterior and lateral margins of the pedicel valve, in *Strophomena concordensis*, is only moderate; the inner margin of this thickened border is rather vaguely defined, and the border is crossed by vascular markings extending as far as the anterior edge of the shell. These vascular markings extend fully a centimeter from the anterior edge. The muscular area is deeply impressed and is limited by a sharp, prominent border, deflected anteriorly so as to produce a median gap. The muscular area is crossed by a median ridge, on each side of which are the impressions left by the adductor muscles.

In the *Ohio Naturalist*, vol. XII, pl. XXII, 1912, Fig. 10 A illustrates a typical interior of the brachial valve, Fig. 10B presents an aberrant form of the pedicel valve in which the marginal thickening lies nearer the edge, is more distinctly defined posteriorly, and is more abrupt anteriorly than usual.

The interior of the brachial valve does not present any distinguishing features. The two-lobed cardinal process, the strongly divergent crural ridges, the median ridge dividing the muscular area anterior to the cardinal process, and the four vascular ridges and intermediate sinuses along the median parts of the valve are

distinctly shown. Of these ridges, the two lateral ones terminate posteriorly within the impressions of the adductor muscles. Posteriorly, the interiors of both valves occasionally are pitted. Aside from the markings already mentioned, numerous minute papillae often may be seen under a lens, the surface appearing smooth to the unaided eye.

From *Strophomena wisconsinensis* this species may be distinguished by its more triangular, subnasute outline, and the finer striation of the exterior surface. The height of the hinge-area also is much less.

The type specimens of *Strophomena concordensis* were found in a partially indurated blue clay layer at the top of the Arnheim bed, a short distance south of the railroad bridge, east of Concord, Kentucky, at creek level.

Strophomena concordensis ranges from the southwestern corner of Butler county, in Ohio, southeastward to Maysville and Concord, along the northern edge of Kentucky. In all of this distance its horizon is confined to the top of the Arnheim, usually in a chunky, bluish, argillaceous rock, although in the southern part of Adams county this gives way to more or less limestone, and southeast of Maysville, in Kentucky, the *Strophomena concordensis* horizon consists practically entirely of limestone layers. Eastward, the chunky, argillaceous rock varies from 5 to 7 feet in thickness, but north of Lebanon, Ohio, its thickness is $4\frac{1}{4}$ feet; opposite the Chautauqua grounds at the southern edge of Montgomery county, it is 3 feet; and westward it is still thinner, disappearing before reaching the western boundary of Butler county. At Oregonia, *Strophomena concordensis* is very rare and occurs only at the base of the chunky argillaceous rock. This locality, and the one south of Lebanon, appear to mark the northern boundary of the area of distribution for this fossil. At many of the localities farther southward, *Strophomena concordensis* occurs in great abundance throughout the entire thickness of the chunky argillaceous rock, at the top of the Arnheim. The interval between this rock and the underlying *Dinorthis carleyi* horizon usually varies from 16 to 20 feet.

Among the areas at which *Strophomena concordensis* does not occur, notwithstanding the presence of the chunky, blue, argillaceous rock at the top of the Arnheim, is the mouth of Lick Run, opposite the mouth of Caesar Creek, in the northern part of War-

ren county; the exposures along Reservoir Creek, north of Lebanon; opposite the Chautauqua grounds, east of the Miami River, at the southern edge of Montgomery county; and 2 miles south of Jacksonburg, in the northern part of Butler county.

At Maysville, Kentucky, *Strophomena concordensis* occurs, associated with *Dalmanella jugosa* in a bluish limestone about 2 feet thick. Lithologically, the rock resembles the base of the Waynesville member, rather than the chunky argillaceous rock seen farther northward.

The most interesting section, however, is that at Concord, in the northern part of Lewis county, where *Strophomena concordensis* is limited to a vertical range of 1 foot, *Streptelasma canadensis* and *Columnaria alveolata* occuring 5 feet above this level, and *Streptelasma canadensis* being found also 5½ feet below the *Strophomena concordensis* horizon. Nothing like this has been observed elsewhere and the section requires further study.

About 2 miles north of Hazelwood, Ohio, northwest of the corner at which Butler, Warren, and Hamilton counties meet, and also 1 mile south of Pisgah, in the same corner of Butler county, specimens of *Strophomena* occur, at the *Strophomena concordensis* horizon, which are comparatively flat and so little nasute anteriorly that they suggest *Strophomena planumbona* and the flatter forms of *Strophomena elongata* rather than *Strophomena concordensis*. In some of these specimens the anterior margin is evenly rounded. It should be noted, however, that they are not of full size, and that at a more advanced age they might have developed to a form more nearly resembling typical *Strophomena concordensis*. The largest specimens of the more quadratic type have a width of 26 mm. with a length of 19 mm., while the largest specimens of the *elongata* type have a width of 30 mm. with a length of 20 mm.

Strophomena concordensis represents a reintroduction of the *Strophomena vicina* type of shell. Its geographical range is limited to the area between Lewis county, in Kentucky, and the eastern part of Butler county, in Ohio. Here it occurs only at the very top of the Arnheim, in strata which perhaps had better be placed at the very base of the Waynesville member of the Richmond. It is not known from the Arnheim of the remainder of Kentucky, or from Indiana or Tennessee. It recurs in the Blanchester division of the Waynesville member in an almost

identical form, associated with *Strophomena nutans*. In fact, *Strophomena nutans* may be regarded as only a depauperate, gerontic form of *Strophomena concordensis*. The range of *Strophomena nutans* also is limited to the more northern exposures along the areas traversed by the Cincinnati geanticline, but, compared with *Strophomena concordensis*, its range is more extended, reaching from Lewis county, in Kentucky, to Dearborn county, in Indiana. Northward, *Strophomena concordensis* finds a near relative in *Strophomena concordensis-huronensis* along the northern parts of Lake Huron and along the southern shores of Georgian Bay. *Strophomena wisconsinensis*, from Wisconsin and Illinois, probably belongs to the same group.

The introduction of *Strophomena concordensis* at the close of the Arnheim was brief, and the accompanying species give no clue as to the direction from which this fauna might have come. In the Blanchester division, however, the related species is associated with *Strophomena neglecta*, which finds its nearest relative in *Strophomena planodorsata* from the Mississippi Valley, ranging from southern Tennessee northward to Minnesota and thence westward. Moreover, the Blanchester division contains also *Austinella scofieldi* and is included between two layers containing *Hebertella insculpta*, two species having an equally extended geographical range along the Mississippi Valley.

From these data it may be concluded that all of these species had some common origin. During the deposition of the Blanchester division of the Waynesville there apparently was a basin extending from Bath, Fleming, and Lewis counties, in Kentucky, northward and northwestward across Ohio, Indiana, and northern Illinois, so as to connect with the Mississippi basin. Apparently *Strophomena concordensis* represents merely one of the first incursions of the fauna which later had a much greater distribution. As far as its appearance in southwestern Ohio is concerned, it appears to have entered from some northern or northwestern source.

Strophomena concordensis-huronensis, var. nov.

(*Plate II, Figs. 1 A, B, C, D, E, F, G, H, J, K*)

In the Richmond group on Manitoulin Island, a species of *Strophomena* is very common at various levels between the *Heb-*

ertella insculpta horizon and a coral horizon, at least 40 feet farther up. At the *Hebertella insculpta* horizon, *Catazyga headi* occurs locally. *Strophomena sulcata* ranges from immediately above the *Hebertella insculpta* horizon upward for a distance of about 20 feet. *Protarea richmondensis, Columnaria alveolata, Calapoecia huronensis, Streptelasma canadensis,* and *Rhynchotrema perlamellosa* begin their range at the *Hebertella insculpta* horizon and continue their range at various intervals to the coral horizon already mentioned. Some of these species are found for a considerable distance beyond this coral horizon. The abundant species of *Strophomena,* here under discussion, ranges from the *Hebertella insculpta* horizon almost up to the coral bed. *Cyclonema bilix* and a small form of *Plectambonites sericea* occur in the lower half of this interval, and *Platystrophia clarksvillensis* also occurs at various levels. *Rhombotrypa quadrata* ranges from the *Hebertella insculpta* horizon upward for about 6 feet. *Zygospira kentuckiensis* ranges from about 17 feet below the coral horizon to layers overlying the coral bed. The latter is characterized by the great numbers of *Columnaria alveolata* and *Calapoecia huronensis* present. Specimens of *Tetradium* and of *Stromatocerium* occur. The chief feature of this coral horizon is not the presence of any characteristic species, not found above or below, but the abundance of *Columnaria* and *Calapoecia,* species which at other levels, especially at lower levels, occur only as isolated specimens.

In general, this section between the *Hebertella insculpta* horizon and the coral bed, 40, 50 or 60 feet higher up, is very suggestive of the upper or Blanchester division of the Waynesville member of the Richmond, while the overlying beds, containing *Beatricea undulata,* may be compared with the Saluda of Indiana and Kentucky. The most conspicuous feature of the lower division of the Richmond, on Manitoulin, is the absence of *Leptaena richmondensis,* a fossil extremely abundant in the Blanchester division of the Waynesville member. On the other hand, the presence of isolated specimens resembling *Strophomena neglecta* and *Strophomena nutans* is highly suggestive. The most striking feature of the section overlying the coral horizon is the absence of *Dinorthis subquadrata* and of *Strophomena vetusta.* It should be remembered, however, that the latter species were driven out of the Indiana and Kentucky Richmond,

by the Saluda invasion, probably from the north, and occur only in the basal layers of the Saluda.

With these preliminary remarks in mind, it will be possible to appreciate the significance of the specimens of *Strophomena* which are so abundant in the lower beds of the Richmond on Manitoulin.

Perhaps the most striking feature of these Manitoulin specimens is their general resemblance to *Strophomena concordensis* and to the similar specimens associated with typical *Strophomena nutans* at Clarksville, Ohio, and elsewhere in Cincinnatian areas. The latter are described under *Strophomena nutans*, and are regarded not merely as descendants of *Strophomena concordensis*, but also as the less aberrant forms of which typical specimens of *Strophomena nutans* are the retarded, gerontic individuals.

The general outline of the shell tends to be subnasute and subpentagonal. It is possible to cull out specimens in which this tendency is strongly marked, and to select others in which the convexity of the shell is more regular, and the general outline is about as evenly rounded as in *Strophomena planumbona*. However, shells in which the tendency toward a subnasute outline is only faint, are more common. The postero-lateral angles usually vary between 80 and 85 degrees, but they frequently are rectangular, and occasionally they may be as acute as 70 degrees. Not infrequently the shell is extended slightly at the hinge-line.

The brachial valve is flattened posteriorly for a distance of about 10 mm., after which the downward flexure of the shell begins. The maximum convexity usually occurs 12 to 15 mm. anterior to the beak. In the subpentagonal shells, the slope from here to the antero-lateral margins is somewhat more rapid than along the median line, thus giving the central part of the valve a slightly humped appearance. Usually the downward curvature of the shell is rather regular anteriorly, but occasionally it is quite abrupt. Sometimes the nasute character of the shell is very pronounced and occasionally an individual is found in which this nasute character is as prominent as in the figure of *Strophomena hecuba* published by Billings in *Paleozoic Fossils*, vol. I, p. 126.

The pedicel valve is rather strongly concave, especially in the more nasute specimens, frequently equalling 3 and 4 mm. in shells 22 to 30 mm. in length. Immediately anterior to the beak, the valve is distinctly convex, the reversal of curvature taking place between 12 and 15 mm. from the beak.

So many of the shells are obliquely wrinkled along the hinge-line that this feature may be said to be characteristic of the Manitoulin species, notwithstanding the numerous individuals in which this wrinkling is inconspicuous or absent. The angle made between the wrinkles and the hinge-line usually varies between 30 and 40 degrees. Radiating striae subequal or alternately larger and smaller, about 12 or 13 in a width of 5 mm., but ranging occasionally from as low as 10 to as high as 14 or 15. Individual specimens are found in which the alternation of single, stronger striae with three finer ones occurs, but the stronger striae rarely are prominent, and this type of striation is not characteristic of the species.

Interior of the pedicel valve very much as in *Strophomena concordensis.* The thickening along the border of the shell in the majority of specimens is low, and is crossed by shallow vascular grooves, which extend halfway from the anterior margin toward the muscular area, in some individuals almost reaching the latter. In other specimens, this thickening is greater and is more distinctly limited posteriorly, but its height rarely exceeds 2 mm., although in one specimen it equalled 3 mm. Only a single specimen (Fig. 8, plate XI) was found in which this thickening was as prominent and "knotted" along the median line as in the typical forms of *Strophomena nutans.* This smaller, gerontic individual may owe its form to the same conditions as those which gave rise to the numerous specimens which are included under typical *Strophomena nutans,* in Ohio and Indiana.

Interior of the brachial valve also essentially as in *Strophomena concordensis.* Crural plates making an angle of 50 degrees with the hinge-line. Posterior part of the adductor muscle scars sharply limited by the callosity which is anterior to the crural ridges and which unites with the median ridge separating the adductor areas. In most specimens, the subparallel ridges traversing the median parts of the valve anterior to the adductor areas, and limiting the vascular grooves, are not distinctly defined except within a short distance of these areas.

The chief difference between the Manitoulin specimens and *Strophomena concordensis* consists in the presence of the oblique wrinkles along the hinge-line. In *Strophomena concordensis*, from Ohio and adjacent Kentucky, the outline of the shell more frequently becomes subtriangular; when the shell is viewed from the side, the posterior flattened part of the brachial valve usually rises more abruptly above the plane passing through the margins of the valve; in consequence, the hump at which the downward flexure of this valve is greatest lies nearer the posterior part of the valve; the curvature from this hump toward the anterior margin usually is less, producing a long slope in this direction, with longer and somewhat flatter antero-lateral slopes, resulting frequently in the more triangular outline already mentioned. It should be emphasized, however, that the differences here noted are not characteristic of all the shells, and are not likely to be observed unless large collections of shells are at hand, in which case the general facies is that here described.

The chief interest in these Manitoulin specimens lies in the fact that from the central type here described, including the vast majority of specimens, there is a line of variation towards specimens which can not be distinguished from *Strophomena planumbona*, but which exist in much smaller numbers. A few specimens also show a line of variation toward *Strophomena nutans*. Individual specimens that can not be distinguished from typical *Strophomena planumbona*, *Strophomena planumbona-gerontica*, and *Strophomena nutans* also occur. Why should these specimens always be isolated?

It is not worth while comparing this species with *Strophomena hecuba* until the genus of that species is known. Its vertical range suggests *Strophonella* instead of *Strophomena*, and the interior of this species has not been described so far. Provisionally, the absence of indistinct concentric wrinkles will be sufficient to distinguish all of the variations of the *Strophomena concordensis* type.

The type specimens of the variety *huronensis* occur in great abundance at the eastern end of Manitoulin Island, at the Clay Cliffs, 3 miles north of Wekwemikongsing. This is the locality long known as Cape Smith, although this Cape lies several miles toward the northward. The clay cliffs are best reached by the long walk over large boulders along the shore. Specimens of the

variety *huronensis* are abundant in the glacial drift northwest of Wekwemikongsing. They are found in place 3 miles south of Little Current, and at numerous localities around Kagawong and Gore Bay. On account of their abundance elsewhere, their absence at Manitouaning, and south of the Indian village, 5 miles southwest of Little Current, should be noted. The same form occurs in the eastward extension of the Richmond, also a short distance above the *Hebertella insculpta* horizon, at various localities south of Cape Rich, and south of Cape Boucher, 2 miles east of Meaford, on the southern shore of Georgian Bay. The same fauna should occur also southeastward, at Streetsville, on the Credit River, and west of Manitoulin, at the northeast end of Drummond Island.

Near Meaford, Ontario, only the lower part of the Richmond section, for 14 feet over the *Hebertella insculpta* horizon, is richly fossiliferous. The overlying part of the Richmond section is formed by a thick series of reddish clays, and shales the latter more or less sandy.

Strophomena nutans, Meek[8]

(*Plate III, Figs. 2 A, C, D, E; Plate IX, Fig. 15; Plate X, Figs. 2 A, B, C; Fig. 2 B on Plate III and Fig. 8 on Plate XI present similar features; Plate X, Figs. 3 A, B, C, D, and Plate IX, Fig. 16, approach Strophomena concordensis.*)

The typical form of *Strophomena nutans* is from the upper or Blanchester division of the Waynesville bed, in Butler, Warren, and Clinton counties, Ohio. This species was described by Meek from material belonging to the U. P. James collection. In this collection, preserved in the Walker Museum, at Chicago University, there is a series of specimens, numbered 65, labelled as types of *Strophomena nutans*, and as coming from Richmond, Indiana. Among this series, only the specimen used for Fig. 1 *c*, on plate VI, of the *Ohio Paleontology*, could be found. The labelling, Richmond, Indiana, probably is entirely incorrect. However, even if the specimen was obtained from the vicinity of Richmond, it should be remembered that the nearest outcrop containing *Strophomena nutans* is 8 miles southwest of Richmond, 1½ miles south of Abingdon, on the eastern side of the Whitewater River.

[8] *Ohio Paleontology*, vol. i, p. 77, 1873.

The specimens represented by figures *A*, *B*, *C*, accompanying the original description, were 23 mm. wide and 21 mm. long. They have a sub-pentagonal outline. Anterior to a line drawn transversely across the center of the shell, the outline is broadly V-shaped, rounded at the anterior extremity. Posterior to this transverse line, the sides of the valve are only moderately divergent or nearly parallel. The posterior part of the brachial valve is flattened. From this flattened area, the shell is deflected strongly toward the anterior margin, especially toward the antero-lateral sides, producing a strongly convex, subnasute appearance, which suggested the term *nutans*. The pedicel valve is rather strongly concave, the maximum depression being about two-thirds of the length of the shell from the beak. The radiating striae are fine, every fourth one tending to be slightly more prominent. The muscular area of the pedicel valve is deeply impressed, and the border of this area rises sharply and prominently above the general surface. The interior of the valve is conspicuously thickened along the border, the amount of this thickening being greatest near the middle of the anterior border, where it presents a very steep slope, having a height of almost 8 mm. above the general plane of the margin of the valve. This thickened border is crossed by strongly impressed grooves, called vascular markings, which are most conspicuous near the median parts of the border, where the latter attains the greatest elevation. Several ridges, limiting vascular grooves, extend posteriorly as far as the anterior border of the muscular area. The space between the muscular area and the thickened border is marked by small ovarian pits.

In other specimens of the same general appearance, the alternation of more prominent striae with sets of three finer striae is shown best by the pedicel valve, but a similar tendency is shown also along the postero-lateral angles of the brachial valve and over the flattened umbonal area. Anteriorly, on the deflected marginal portion, the striae are coarser, and either alternating in size or approximately subequal. About 13 striae occupy a width of 5 mm. Some specimens are fully mature when they have reached a width of only 20 mm., while others attain a width of 25 mm., a length of 21 mm., and a convexity of 10 mm. The thickened border along the interior of the pedicel valve may reach a height of 10 mm., measured from the anterior margin of

the valve. The ovarian pits usually are conspicuous only on the posterior part of the pedicel valve. Occasionally the shell is slightly extended at the hinge-line. The brachial valve, of course, presents a similar outline. The impression of the adductor muscles usually is deep, and strongly defined by the callosity bordering the anterior part of the crural plates and the cardinal process. There is a strong medial elevation, separating the adductor scars, anterior to which are the median ridges separating the vascular grooves.

While it is evident that the smaller specimens, described in the preceding lines, are to be regarded as the types of *Strophomena nutans,* it must be remembered that they are gerontic individuals secured by selection from a much larger series, in which the callosity along the interior border of the pedicel valve is much less conspicuous, and which frequently attain a much larger size. Some of these larger specimens, occurring in the same slabs of rock, for instance in the Rocky Hollow northwest of Clarksville, Ohio, attain a width of 32 mm. a length of 25 mm., with a convexity of 14 mm. In all of these larger specimens, the thickening along the interior border of the pedicel valve is much less conspicuous, not exceeding a height of 5 mm. above the plane passing through the margins of the valve, or a height of 6 mm., measured along the slope of this border. Moreover, this thickened border is less distinctly limited on the posterior side, and the transverse radial vascular grooves extend farther toward the muscular area. In still other shells, from the same layers, the thickening along the border becomes slight, and the shallow, radial vascular grooves are inconspicuous. Shells of this type closely resemble *Strophomena concordensis,* from the top of the Arnheim, and some individuals could scarcely be distinguished from the latter if their origin were not known. In fact, the smaller, typical specimens of *Strophomena nutans* are regarded as the retarded, gerontic forms of *Strophomena concordensis.* Fig. 1 *d,* accompanying the original description of this species by Meek, may represent the interior of the brachial valve of one of these larger forms associated with the smaller, narrower, and more typical forms of *Strophomena nutans.* (Plate X, Fig. 3.)

Where abundant material is at hand, there is no difficulty in distinguishing between *Strophomena nutans* and *Strophomena con-*

cordensis. *Strophomena nutans* occupies a later horizon and may be regarded as a direct derivative of the *Strophomena concordensis*.

At Clarksville, in Clinton county, unquestionably one of the type localities, the range of *Strophomena nutans* begins 12 feet above the lower *Hebertella insculpta* horizon, in the Blanchester division of the Waynesville bed.

Hebertella insculpta occurs at several horizons in Cincinnatian areas: at the base of the upper or Blanchester division of the Waynesville; from 25 to 40 feet higher, at the base of the Liberty bed; and at a third horizon, between 15 and 20 feet above the base of the Liberty.

At the base of the Blanchester division, *Hebertella insculpta* is distributed throughout Ohio, from Eagle Creek, about 5 miles west of West Union, in Adams county, to the vicinity of Oxford, in the northwestern part of Butler county. At the base of the Liberty bed, it extends from Wyoming, in the southern part of Fleming county, Kentucky, throughout Ohio, to Madison, in Jefferson county, Indiana. At the third horizon, between 15 and 20 feet above the base of the Liberty, it is known east of Weisburg, in the northwestern part of Dearborn county, and 1 mile north of Brownsville, in Union county, Indiana. The vertical and geographical distribution of *Herbertella insculpta* in this lower part of the Liberty member requires further study. Two miles east of Cross Plains, in the southeastern corner of Ripley county, a few specimens of *Hebertella insculpta* occur near the base of the *Dinorthis subquadrata* zone, the latter being separated from the top of the main *Hebertella insculpta* horizon, 5 feet thick, which occurs at the base of the Liberty, by an interval of $3\frac{1}{2}$ feet.

The lower *Hebertella insculpta* horizon, at the base of the Blanchester division of the Waynesville, introduces a new Richmond fauna. Here, or immediately above this horizon, *Dinorthis carleyi* makes its second appearance, and *Catazyga headi* comes in.

Strophomena nutans and *Strophomena neglecta* make their first appearance usually between 7 and 12 feet above the lower *Hebertella insculpta* horizon. *Strophomena vetusta-precursor* usually comes in later than the other two species, although commonly before the disappearance of *Strophomena neglecta*. Frequently *Strophomena vetusta-precursor* continues later than *Strophomena*

neglecta, and occasionally *Strophomena nutans* is seen earlier than *Strophomena neglecta,* so that the order of succession becomes *Strophomena nutans, Strophomena neglecta, Strophomena vetusta-precursor,* with the range of *Strophomena neglecta* overlapping that of the two other species.

At Moores Hill, Indiana, and at Oxford and Oregonia, Ohio, the total thickness of this *Strophomena* section, at the middle of the Blanchester division, including the three species named, equals about 12 feet. At Jacksonsburg and Clarksville, Ohio, it equals 8 feet. At Canaan, in the northern part of Jefferson county, Indiana, in Adams county, Ohio, and at Concord, Kentucky, it equals only 3 or 4 feet. At Moores Hill, and Weisburg, Indiana, and at Oregonia and Clarksville, Ohio, the top of this *Strophomena* section extends to within 5 or 6 feet from the base of the upper *Hebertella insculpta* zone, which forms the base of the Liberty bed. Where the *Strophomena* section is limited to only several feet, its distance from the upper *Hebertella insculpta* horizon may equal 10 to 15 feet.

The greatest vertical range of *Strophomena nutans* usually does not exceed 2 or 3 feet, but occasionally equals 7 feet.

The geographical range of *Strophomena nutans* extends from the southwestern part of Adams county, 2 miles northeast of Bradyville; northward as far as the Narrows, east of the Pinnacles, 4 miles southwest of Dayton, Ohio; westward to the northern edge of Union county, a mile and a half south of Abingdon, Indiana, and southward to Moores Hill, also in Indiana.

Fig. 2 *B,* on plate III of this Bulletin, presents a view of a specimen of *Strophomena,* somewhat resembling *Strophomena nutans,* from the Whitewater beds at Tate Hill, east of the Focke slaughter house, on the Springfield pike, in the eastern part of Dayton, Ohio. The thickened anterior border ascends vertically a distance of 7 mm. The presence of a similar outline and of a similar considerable thickening of the interior border of the pedicel valve may not be indicative of any direct relationship of this shell to *Strophomena nutans.* Similar conditions may give rise to similar forms at different times without predicating a similar line of descent.

A fragment of *Strophomena,* resembling *Strophomena nutans,* was found 3 miles north of Wekwemikongsing, on the eastern shore of Manitoulin Island (plate XI, Fig. 8).

Strophomena planumbona, Hall[9]

(Plate VIII, Figs. 1 A, B, C, D, E; Plate IX, Figs. 3 A, B; Plate IV, Figs. 1, 2, 3, 4; Figs. 3 A, B, are typical)

The types of *Strophomena planumbona*, numbered 918–3, are preserved in the American Museum of Natural History in New York City. They are labelled as coming from Cincinnati, Ohio, but the species occurs only at horizons belonging stratigraphically above the highest beds exposed at Cincinnati. In the original description the localities mentioned are Cincinnati and Oxford (Ohio), Madison (Indiana), and Maysville (Kentucky). The species does not occur at Cincinnati, although specimens have been sent out by Cincinnati collectors to many museums in this country and in Europe. The specimens found at Maysville, Kentucky, here are described as *Strophomena concordensis*. At Oxford, Ohio, and Madison, Indiana, *Strophomena planumbona* is common in the Clarksville and Blanchester divisions of the Waynesville bed. Lithologically, the types closely resemble specimens of this species collected at Madison, Indiana, but their exact origin is unknown. Undoubtedly they were obtained from the Waynesville bed.

Fig. 4 *a*, on plate 31 *B*, *New York Paleontology*, vol. I, represents the pedicel valve. The specimen is entire, presenting both valves. The chief feature of the pedicel valve is the presence of distinctly stronger striae, separated by much finer striae, usually three in number. Anterior to the middle of the shell, the middle one of the group of finer striae frequently becomes more conspicuous, and additional finer striae come in, preserving the appearance of stronger striae, each pair being separated by several finer striae. The tendency toward the alternation of single stronger striae with two or three distinctly finer striae is shown also by the brachial valve, especially along the lateral margins, and over the flattened portions of the valve as far anterior to the hinge-line as the area where the more rapid downward curvature of the shell begins. Along the anterior parts of the brachial valve, there is a tendency toward an alternation between single stronger and single finer striae. In slightly weathered specimens, in which the intermediate finer striae are not readily

[9] *New York Paleontology*, vol. i, p. 112, 1847.

detected, the anterior parts of the shell appear ornamented by rather distant stronger striae of which 8 or 9 may appear in a width of 5 mm.

On the brachial valve represented by Fig. 4 *b*, the striae along the anterior margin are more nearly subequal, owing to the increase in size of the intermediate finer striae anteriorly, and here about 15 or 16 striae are noted in a width of 5 mm.

In the specimen represented by Fig. 4 *a*, the length is 20 mm.; the width, 25 mm.; and the convexity, about 6 mm. In the specimen represented by Fig. 4 *b*, this convexity equals 7 mm., and in the most gerontic specimens it may attain even 11 mm. The shells have a distinctly quadrate outline, a very slight contraction in width immediately anterior to the hinge-line being balanced by a slight elongation at the hinge-line itself. The brachial valve is distinctly flattened for a distance varying from 12 to 14 mm. anterior to the hinge-line. The concavity immediately anterior to the beak is slight. The hinge-area is rather high, considering the width of the shell, and diminishes rather gradually until near the postero-lateral angles of the shell. In specimen 4 *a*, the height of the hinge-area is 3.3 mm. at the beak; in specimen 4 *b*, it is 3 mm.

In general, the shells of *Strophomena planumbona* are small or attain only medium size. The posterior third of the brachial valve is strongly flattened. Surface striae, fine and thread-like, about 13 in a width of 5 mm.; occasionally as few as 11, rarely as many as 20. Muscular scars of the pedicel valve, producing a circular, deeply impressed area, bordered on each side by a curved, sharply elevated ridge, deflected slightly anteriorly, producing an anterior median gap. Median vascular markings often distinct. The interiors of the pedicel valves are thickened toward the anterior and lateral margins, this thickening often being rather distinctly defined posteriorly, and crossed by branching vascular grooves. Along the sides of the pedicel valves, this interior thickening becomes narrower, though still fairly distinct and showing vascular markings.

In Stony Hollow, northwest of Clarksville, in Clinton county, Ohio, *Strophomena planumbona* makes its first appearance 1 foot above the 5-foot clay layer in which *Orthoceras fosteri* is common. It therefore begins at the base of the Clarksville division, and from this level it continues through the Clarksville

division to the base of the lower *Hebertella insculpta* horizon. The specimens are quadrate in outline, and the radiating striae are subequal in size, or alternately larger and smaller. As a matter of fact, the variety *Strophomena elongata* is more common in the Clarksville bed, at this locality, than the more typical *Strophomena planumbona*, which has a shorter hinge-line. It is evident that *Strophomena planumbona* is connected with *Strophomena elongata* by specimens in which the postero-lateral angles are only moderately acute. Specimens of this type become common in the upper part of the Blanchester division and in the lower half of the Liberty.

No *Strophomenas* occur in the lower part of the Blanchester division. Specimens of *Strophomena planumbona*, with a quadrate outline, come in at the same horizon as the first specimens of *Strophomena nutans* and *Strophomena neglecta*. Near the middle of the Blanchester division, some of these quadrate forms have a rather high hinge-area, considering the size of the shell, with a corresponding increase of the size of the cavity enclosed between the two valves. Moreover, some of the specimens have the alternation of three finer striae with single larger striations, which is characteristic of the type of *Strophomena planumbona*. In fact, it is probable that the types of *Strophomena planumbona* were secured from the upper half of the Blanchester division of the Waynesville member. In some of these specimens, the alternation of three finer striae with a single stronger striation does not continue as far as the anterior margin of the shell, the striae on the deflected anterior slopes being more nearly subequal.

Specimens of *Strophomena planumbona*, with a quadrate outline and with subequal radiating striae, occur also in the Liberty. Here they are associated, however, with more numerous specimens in which the postero-lateral angles are more acute, and in which the oblique wrinkling, characteristic of the type of *Strophomena subtenta*, is seen more frequently. In fact, it is probable that the type of *Strophomena subtenta* was obtained from the lower part of the Liberty. Similar specimens occur in the upper part of the Blanchester division, but in these the oblique wrinkling is much rarer. As a matter of fact, the oblique wrinkling occurs occasionally even in the quadrate forms of *Strophomena planumbona* found in the upper part of the Blanchester division.

Specimens with a successive alternation of three finer radiating striae with a single stronger striation occur also among the forms with moderately acute postero-lateral angles, which are found in the lower Liberty.

It is possible that *Strophomena planumbona* ranges up into the Whitewater bed. There is no doubt that *Strophomena vetusta* is the predominating species in the Whitewater section, and occurs here almost to the exclusion of other forms, but occasionally specimens are found which resemble *Strophomena planumbona* so much that the presence of the latter species in the Whitewater member can not be denied without further investigation.

Strophomena planumbona and *Strophomena subtenta* were described by Hall in vol. I, of the *New York Paleontology.* Since *Strophomena planumbona* was described on an earlier page, this name should be adopted for both forms if *Strophomena subtenta* proves not to be distinct.

The types of these forms are readily distinguishable. In *Strophomena planumbona,* there is a repeated alternation of three finer striae with a single more prominent one. In the type of *Strophomena subtenta,* on the contrary, the radiating striae are more nearly subequal. The type of *Strophomena subtenta,* moreover, is obliquely wrinkled along the hinge-line.

An attempt to distinguish these forms in the field, however, where the specimens are very numerous, fails to substantiate the distinctness between these two supposed species. It is evident, for instance, that the oblique wrinkling, in *Strophomena subtenta,* is conspicuous only in selected specimens, and that it is entirely absent in the majority of specimens which must be referred to *Strophomena subtenta,* since they occur in the same layers and have the same exterior and interior markings, excepting only the presence of the oblique wrinkling along the hinge-line. Moreover, it is not possible to distinguish between *Strophomena planumbona* and *Strophomena subtenta* on the basis of the exterior markings. In the great majority of specimens, the radiating striae are subequal in size, or are alternately larger and smaller. Specimens in which three finer striae alternate repeatedly with a single stronger striation are rather few in number and occur associated with the former in such a manner that it is very evident that they represent only individuals belonging to the same species, and not even a distinct variety.

The first appearance of *Strophomena planumbona*, in Cincinnatian areas, appears to have been about 1 or 2 feet above the *Orthoceras fosteri* horizon, a clay section which, in Clinton and neighboring counties, in Ohio, immediately underlies the middle or Clarksville division of the Waynesville. *Strophomena planumbona* occurs at this horizon at Clarksville, in Clinton county; and at Fort Ancient, Oregonia, and 1½ miles south of Mount Holly, in Warren county. This probably is the horizon of the first specimens along Bush Run, 1 mile northeast of Somerville, in the southern edge of Preble county; and the first specimens seen in the section along the stream east of Moores Hill, in Dearborn county, Indiana. The first specimens seen at Concord, in Lewis county, and at Sunset and Wyoming, in Fleming county, Kentucky, probably belong in the upper part of the Clarksville division. In fact, *Strophomena planumbona* is widely distributed in the upper part of this division, and becomes abundant at certain horizons in the Blanchester division, and in the Liberty member.

At Concord, in Lewis county, Kentucky, and at Sunset, in Fleming county, *Strophomena planumbona* occurs as low as 27 feet below the base of the Liberty. At Wyoming, in Fleming county, it is found 22 feet below the Liberty. At Owingsville, in Bath county, it occurs immediately below the *Strophomena neglecta* horizon, 16 feet below the lowest *Dinorthis subquadrata* specimens.

Along the pike, east of Howards Mill, in Montgomery county, *Strophomena planumbona*, perhaps accompanied by *Strophomena vetusta*, occurs 52 feet below the Clinton. Half a mile west of Spencer, in the same county, *Strophomena planumbona*, also possibly accompanied by *Strophomena vetusta*, occurs 48 feet below the Clinton. A mile and a half northwest of Indian Fields, in Clark county, *Strophomena vetusta* occurs 55 feet below the Clinton, and *Strophomena planumbona*, associated with *Rhynchotrema capax*, ranges from 10 to 18 feet lower. At Merritts Ferry, at the mouth of the Red River, in the southern edge of Clark county, the layer containing *Tetradium*, *Stromatocerium*, and *Columnaria* occurs 90 feet below the Clinton. North of Ophelia, 4 miles north of Richmond, in Madison county, the additional presence, at the same horizon, of *Calapoecia*, and *Beatricea*, associated with *Strophomena planumbona*, *Rhynchotrema capax*,

Streptelasma canadensis, and other fossils, suggests a probable equivalency of this coral horizon to a similar assemblage of fossils at the base of the fossiliferous section beneath the Saluda horizon, in Jefferson, Bullitt, Nelson, Washington, and Marion counties, in the more western part of Kentucky. This horizon is regarded as belonging at the base of the Liberty section.

The statigraphical position of the specimens of *Strophomena* at Howards Mill, Spencer, and Indian Fields, is regarded as at least as high as the middle of the Blanchester division of the Waynesville. Owing to the fact that southward the vertical distribution of the more characteristic Richmond brachiopoda becomes rapidly restricted, until at Owingsville it is confined to the basal part of the Liberty and the upper half of the Blanchester, it is assumed that this is the horizon most likely to furnish fossils farther southward, in Montgomery and Clark counties. At Owingsville, *Dinorthis subquadrata, Rhynchotrema capax,* and *Streptelasma canadensis* occupy a horizon 3½ feet thick. *Leptaena rhomboidalis* and *Plectambonites sericea* occupy a section 1½ feet thick, immediately beneath, and are regarded as forming the base of the Liberty here, the *Hebertella insculpta* layer being absent. *Strophomena neglecta* and *Strophomena vetusta* range from 10 to 11 feet below the top of the Waynesville, and *Strophomena planumbona* occurs half a foot lower. As a matter of fact, the *Strophomena* horizons in Montgomery and Clark counties may belong even as high as the upper Liberty. In the absence of fossils distinctly diagnostic of the Liberty or of the Waynesville, an element of uncertainty must remain.

Since at Merritts Ferry the layer with *Tetradium, Stromatocerium* and *Columnaria* occurs 90 feet below the Clinton, it is probable that the horizon in the northeastern part of Madison county, 1 mile east of College Hill, containing poor specimens of *Strophomena* and *Streptelasma,* 93 feet below the Clinton, belongs to the same horizon, namely, the base of the Liberty. *Strophomena sulcata* ranges at the same locality from 31 to 40 feet beneath the Clinton, in strata regarded as equivalent to the Whitewater. At Cobb Ferry, nearly 3 miles southeast of College Hill, *Strophomena vetusta* and *Streptelasma canadensis* occur between 54 and 63 feet below the Clinton, and *Streptelasma canadensis* ranges about 5 feet lower. This also should belong to the Liberty horizon.

The horizon with *Tetradium* and *Columnaria* may be traced as far southward as the hill east of the Preachersville pike, 4 miles southeast of Lancaster, in Garrard county, where it is 70 feet below the Clinton, and to various localities east of Rowland, in the northeastern part of Lincoln county, where it is about the same distance below.

In all of the preceding cases, the term Clinton implies the Brassfield member at the base of the Silurian of Kentucky, and not the equivalent of the typical Clinton of New York, which finds its representative in the Crab Orchard section of Kentucky, and in the immediately overlying West Union member.

On the western side of the Cincinnati geanticline, a similar restriction in the vertical range of the brachiopod fauna of the Richmond takes place. At Madison, in Jefferson county, Indiana, and at Milton, on the opposite side of the river, in Kentucky, the lowest specimens of *Dinorthis subquadrata* occur about 75 feet below the base of the Clinton, and *Hebertella insculpta* is found about 7 or 8 feet lower, at the base of the Liberty bed. *Strophomena planumbona* occurs in the lower part of the Liberty, and also in the upper part of the Waynesville, the lowest specimens being found 30 feet below the lowest specimens of *Dinorthis subquadrata*. At the mouth of Bull Creek, in Clark county, Indiana, the lowest specimens of *Dinorthis subquadrata* occur 63 feet below the Clinton, and only the upper 20 feet of the Waynesville bed are richly fossiliferous, containing *Strophomena elongata* and *Strophomena planumbona*. *Zygospira kentuckiensis* occupies the underlying part of the section, 8 feet thick, and *Tetradium* is abundant from 8 to 12 feet lower.

About 5 miles south of the mouth of Bull Creek, 2 miles northwest of Brownsboro, in Oldham county, the lowest specimens of *Dinorthis subquadrata* occur 60 feet below the Clinton. *Strophomena vetusta* occurs in the overlying part of the Liberty section, 12 feet thick, but no species of *Strophomena* was noted in the underlying fossiliferous section, the upper part of the Waynesville. Along the railroad from Jeffersontown eastward to Fisherville, in the eastern part of Jefferson county, in Kentucky, a conspicuous *Columnaria vacua* horizon is found below the richly fossiliferous Liberty section, which there includes *Strophomena vetusta, Dinorthis subquadrata*, and, near the base, also *Strophomena planumbona*. Specimens of *Strophomena planum-*

bona-elongata occur about 13 feet below this *Columnaria* horizon, in the upper Waynesville. South of Jefferson county, *Strophomena planumbona* is known, in the Waynesville, only from the strata immediately beneath the *Columnaria* horizon, the most southern occurrence known in Kentucky being about 4 miles north of Bardstown.

Specimens closely similar to *Strophomena planumbona* occur in the Waynesville division of the Richmond at Dismukes Station, 4 miles north of Gallatin, in Tennessee.

The fossiliferous part of the Liberty section also thins out southward. The most southern localities for *Dinorthis subquadrata* are at Bardstown, and on Mill Creek, 4 miles east of Bardstown. At these localities *Dinorthis subquadrata* is associated with *Strophomena vetusta,* no specimens of *Strophomena planumbona* having been found. The most southern localities for *Strophomena planumbona* in the Liberty are in the vicinity of Mount Washington, in Bullitt county, where they occur only in the basal part of the Liberty, immediately over the *Columnaria* horizon. Northward, in Indiana and Ohio, *Strophomena planumbona,* especially the variety *Strophomena subtenta,* is very abundant in the Liberty, especially its lower half.

The richly fossiliferous horizon at the base of the Liberty may be traced as far south as Raywick, in the western part of Marion county, but the only species of *Strophomena* seen here is *Strophomena sulcata.*

Strophomena planumbona is known also from the southern base of Jeptha Knob, in the eastern part of Shelby county, a short distance south of J. P. Wellman's barn. Farther southward, *Strophomena vetusta* is seen. Both exposures probably belong to the Liberty horizon, although no specimens of *Dinorthis subquadrata* were found.

It is doubtful whether *Strophomena planumbona* occurs in the Whitewater bed. Interiors of pedicel valves suggesting the presence of *Strophomena planumbona* are seen in the Whitewater member at several localities near Dayton, Ohio, but the exteriors as well as the interiors of these valves must be seen, in order to distinguish between some specimens of *Strophomena vetusta* and some of *Strophomena planumbona.* At any rate, *Strophomena vetusta* is very abundant in the Whitewater, and while *Strophomena planumbona* may be present occasionally, it certainly must occur only as occasional or sporadic specimens.

Judging from the fact that *Strophomena planumbona* makes its appearance earlier in the Waynesville section in Ohio and Indiana than southward in Kentucky, it is regarded as another of the species having a northern or northwestern origin as far as the immediate territory under consideration is concerned. It evidently is closely related to species distributed from Illinois southward as far as southern Tennessee. The connection with this western basin, however, appears to have been by way of northern Illinois rather than by means of some more southern channel. This leaves the general question as to the origin of the Mississippi Valley Richmond entirely untouched.

Strophomena planumbona-elongata, James[10]

(*Plate IV, Figs. 1 A–L; Plate IX, Figs. 4 A, B*)

The types of *Strophomena elongata*, James, numbered 510, are preserved in the James collection, in the Walker Museum, at Chicago University.

The types present the following characteristics. General outline of the shell broadly semicircular, elongate along the hinge-line. Angle between the general lateral outline and the hinge-line between 60 and 70 degrees. Brachial valve convex, especially from front to rear; the transverse section much less convex, moderately flattened toward the beak, especially over an area extending 8 to 10 mm. from the posterior margin. Usually an almost imperceptible median depression extends forward from the beak about 6 or 7 mm. Radiating striae of the brachial valve subequal and of medium size, about 14 or 15 in a width of 5 mm. Radiating striae of pedicel valve slightly finer, about 16 or 17 or 18 in a width of 5 mm. at 20 mm. from the beak. Greatest convexity of the pedicel valve near the middle or slightly anterior. Hinge-area of medium height, narrowing toward the extremities, equalling 2.8 mm. at the beak.

Width of one of the type specimens, 35 mm.; length 22 mm.; convexity at 11 mm. from the beak, 8 mm. Length of the hinge-area, 34 mm.; height at the beak, 2.8 mm. Maximum convexity of the hinge-area, observed among other type specimens, 4.4 mm., in a shell 38 mm. wide along the hinge-line, 23.5 mm. long, and with a convexity of 13 mm. This was a very obese specimen.

[10] *Cincinnati Quarterly Journal of Science*, vol. i, p. 240, 1874.

Figs. 4, *A*, *B*, on plate IX of this Bulletin present posterior and lateral outlines of the type from the James collection which is illustrated by Fig. 1, *I* on plate IV.

Strophomena elongata differs from typical examples of *Strophomena planumbona* chiefly in its greater width along the hinge-line and in its much greater convexity from front to rear. The shells frequently attain a width of 40 mm. along the hinge-line, and the postero-lateral angles often reach 70 degrees. Not all the shells have acute postero-lateral angles. Some specimens have considerable width compared with the length, but the angles at the hinge-line are almost rectangular. In some specimens the ratio of width to length is as seven to four. The specimens with acute postero-lateral angles and with strongly convex brachial valves have a subtriangular appearance, but there is a tendency toward a flattening of the antero-lateral slopes, the anterior outline remaining more or less evenly rounded. The convexity from front to rear frequently equals half the length. In the original description the shell is stated to narrow rapidly to the front, giving it a triangular outline. It is evident from the types that this statement is exaggerated and misleading.

The muscular area of the pedicel valve is broadly oval. It is deeply impressed, the lateral borders are prominent and sharp, being deflected toward the front anteriorly, leaving a median gap. A low median ridge, sometimes bordered on each side by a narrow, linear area representing the adductors, divides the muscular area. On each side of this area the inner surface of the valve not infrequently is pitted or covered with low elongate papillae, usually interpreted as ovarian markings. The inner margin of the shell is thickened, especially anteriorly, and this thickening is crossed more or less radially by vascular markings, which may be traced a short distance toward the muscular area.

Owing to the considerable convexity of the brachial valve, the interior surface appears deeply concave. The adductor muscle areas are deeply impressed posteriorly, and sometimes distinctly limited also anteriorly, but usually several radial ridges, probably to be interpreted as vascular markings, cross the anterior outline. The two inner ridges of this set are extended anteriorly along the median part of the valve. The crural ridges are prominent and limit the adductor areas posteriorly. A broad ridge extends forward from the callosity anterior to the cardinal process.

Specimens of this type are common in the middle or Clarksville division of the Waynesville bed, but they occur also in the upper or Blanchester division. Not infrequently they are wrinkled obliquely along the hinge-line. As a rule, the radiating surface striae alternate moderately in size or are approximately equal.

The vertical and geographical range of the variety of *Strophomena planumbona* which was described by James as *Strophomena elongata* is very imperfectly known. No attempt has been made so far to determine whether it has any value as a diagnostic fossil, characteristic of some definite horizon.

In Stony Hollow, northwest of Clarksville, in Clinton county, Ohio, *Strophomena elongata* makes its appearance 1 foot above the base of the Clarksville division of the Waynesville member, or 1 foot above the top of the 5-foot clay section in which *Orthoceras fosteri* is common. From this horizon, *Strophomena elongata* ranges throughout the Clarksville division, occurring as far up as the lowest layers belonging to the lower *Hebertella insculpta* horizon. Throughout this Clarksville division, the radiating striations usually are subequal in size, or alternately larger and smaller. Specimens in which 3 finer striae occur between each pair of stronger striations are found, but are not common and are not characteristic of this variety.

No species of *Strophomena* is found in the lower half of the Blanchester division of the Waynesville member, between the lower *Hebertella insculpta* horizon and the lowest horizon at which *Strophomena nutans* and *Strophomena neglecta* make their appearance. This is an interval of 12 feet.

The more quadrate forms of *Strophomena planumbona*, which are present also throughout the Clarksville division, reappear at the lowest horizon containing *Strophomena nutans* and *Strophomena neglecta*, and continue to the top of the Waynesville member, and beyond the middle of the Liberty. The variety known as *Strophomena elongata*, however, appears to be represented only by a few, not very typical, specimens near the base of the upper *Hebertella insculpta* horizon, in the upper part of the Blanchester division of the Waynesville.

Along the Stony Brook, 1 mile southeast of Fort Ancient, in Warren county, Ohio, typical *Strophomena elongata* also occurs in the Clarksville division, making its first appearance 2 feet

above the *Orthoceras fosteri* layer. It probably occurs in the Clarksville division also at Wyoming, in the southern part of Fleming county, where *Strophomena elongata* is found 9 feet below the *Strophomena neglecta* horizon. At Sunset, in the same county, *Strophomena elongata* occurs at various levels within 12 feet of the base of the upper *Hebertella insculpta* horizon, in the upper or Blanchester division of the Waynesville. It appears to occur in the Blanchester division, or its equivalent, also along Silver Creek, northeast of Dunlapsville, in Union county, Indiana; at Moores Hill, in Dearborn county; at Madison, in Jefferson county; and at the mouth of Bull Creek, in Clark county. East of Jeffersontown, in the eastern part of Jefferson county, Kentucky, *Strophomena elongata* occurs 13 feet below the *Columnaria* horizon, in strata regarded as upper Waynesville.

These data suggest a range from the lower Clarksville to the top of the Blanchester, with a gap in the lower half of the Blanchester.

Strophomena planumbona-subtenta, Hall[11]

(*Plate IV, Figs. 4, A, B, C, D; Plate VIII, Figs. 2 A, B; Plate IX, Fig. 2*)

The name *Strophomena subtenta* was first published by Conrad, in the *Fifth Annual Report of the New York Geological Survey,* in 1841, on page 37, but no description of the species was given until Prof. James Hall published his report in the *New York Paleontology,* vol. 1, in 1847. On page 115 of this volume, Professor Hall stated:

> I find among the drawings of Mr. Conrad, the figure of a Trenton species, with this name attached. I have not seen the same in New York, but the specimen figured is from a western locality. It bears all the essential marks of the species cited, and I have therefore introduced it under that name. The strong oblique wrinkles form a distinguishing feature.
>
> *Position and locality.* In the Blue limestone of Ohio, associated with *Leptaena alternata, Leptaena sericea,* and *Orthis testudinaria.* Oxford (Ohio). Trenton Falls, on the authority of Mr. Conrad.

From these notes it is evident that the specimen figured by Hall on plate 31 *B* as *Leptaena subtenta* is the same specimen

[11] *Strophomena subtenta,* Hall, *New York Palentology,* vol. i, p. 115, 1847. *Strophomena plicata,* Meek, *Ohio Paleontology,* vol. i, p. 81, 1873.

as that figured by Conrad and accompanying his unpublished manuscript.

The type of *Strophomena subtenta,* numbered 922–2, is preserved in the American Museum of Natural History, in New York City. It is a brachial valve, 19 mm. in length, 26 mm. in width, and 5 mm. in convexity. The concavity anterior to the beak is slight, and the flattening of the posterior parts of the valve scarcely extends farther than 11 mm. from the posterior margin of the shell. The divergent wrinkles along the hinge-line are distinctly defined. The postero-lateral angles of the shell are essentially rectangular, but rounded at the apices of the angles. The surface striae are subequal in size, and vary from 5 to 7 in a width of 2 mm. along the anterior margin of the shell, the first number being more nearly typical. Unfortunately the type specimen does not present the surface features of the pedicel valve, but other specimens show that the surface striae of the latter also are subequal in size, but are slightly finer than those in the brachial valve.

A comparison of the type of *Strophomena subtenta* with those of *Strophomena planumbona* suggests that the former might be distinguished from the latter by the oblique wrinkling along the hinge-line and by the subequal surface striae. As a matter of fact, however, the oblique wrinkling is soon found, in the field, to be an individual characteristic, not uncommon in the individuals at some localities, for instance at Concord, Kentucky, but practically absent at other localities at the same horizon. In the same manner, the subequal size of the surface striae has been found to be an unreliable feature, specimens possessing these characteristics grading into others in which every third or fourth striation is more prominent.

After having repeatedly seen the types of *Strophomena planumbona* and *Strophomena subtenta,* and having had them several times in my possession, owing to the courtesy of Professor Whitfield and Dr. Hovey, I spent several days at Clarksville, at Oregonia, and along the creek south of Jacksonburg, northwest of Trenton, Ohio, and elsewhere, localities at which it was possible to secure specimens from every foot of the section, in order to learn if it might not be possible to make at least some use of *Strophomena subtenta* as a variety characterizing some horizon, but without success. The best that can be said is that typical

specimens of *Strophomena subtenta,* with the oblique wrinkles and subequal striae, were found more frequently in the lower part of the Liberty, for instance at Concord, Kentucky; at Clarksville, near Dayton, west of Camden, and near Oxford, Ohio; also at Richmond, and thence southward to the mouth of Bull Creek, in Indiana. While especially common in the lower half of the Liberty bed, it is found also in the upper half of the Blanchester, and in the Clarksville division, its range being coterminous with that of typical *Strophomena planumbona.* In the other direction, upward, it is found as high as the top of the Liberty.

Among specimens of *Strophomena planumbona* without the oblique wrinkles, there is every variation at the same horizon from subequal striae to those with every second or fourth striation distinctly more prominent. Moreover, the oblique wrinkling occurs both in the subequally and in the unequally striated shells, so that it has been found impossible to make use of either feature or of both combined in the discrimination of *Strophomena subtenta* from *Strophomena planumbona* in the field, not from selected specimens.

The type of *Strophomena subtenta* came from the vicinity of Oxford, Ohio. While *Dalmanella jugosa* (*Orthis testudinaria* of Hall) is common in the Fort Ancient and Clarksville divisions of the Waynesville bed, and practically is absent above the middle of the Blanchester division, it by no means follows that the type of *Strophomena subtenta* came from the Clarksville division of the Waynesville. At the time of the original description of that species, the various horizons of the Cincinnatian fossils were not as carefully discriminated as later, and the fact that *Strophomena subtenta* occurred in the same general neighborhood as *Dalmanella jugosa* might have been considered sufficient to regard them as associated.

While the exact horizon from which the type of *Strophomena subtenta* was obtained is somewhat in doubt, there is no uncertainty about that of *Strophomena plicata,* Meek, since no strata below the Liberty are exposed near the base of the hills at Richmond, Indiana. The nearest exposure of the upper *Hebertella insculpta* horizon, at the base of the Liberty, below the lowest exposures containing *Dinorthis subquadrata,* occurs 4 miles down the river, from Richmond, a quarter of a mile east of the mouth of the Elkhorn Creek, in the lowest exposures on that stream.

Plectambonites sericea has a considerable range in the Liberty bed, not only in Wayne county, in Indiana, but also in Preble county, Ohio, and in the adjacent counties, and must be used with care in determining the base of the Liberty. It is the second great influx of *Hebertella insculpta*, followed this time in close succession by *Dinorthis subquadrata*, which marks the base of the Liberty.

Strophomena planumbona-gerontica, var. nov.

(*Plate IV, Figs. 2 A, B, C; Plate XI, Fig. 6*)

One of the extreme variations of *Strophomena planumbona* is remarkable for its decidedly gerontic appearance. The shells are rather small and very thick. The brachial valves are strongly convex. The hinge-area of the pedicel valve is distinctly higher along its entire length than in ordinary specimens of this species. The general outline of the shell is semicircular, or subquadrate. The length usually varies between 26 and 33 mm. The ratio of the length to the width along the hinge-line varies from 0.87 to 0.68. The ratio between the depth or greatest convexity of the shell and its length usually varies between 0.50 and 0.58. The gerontic character frequently is indicated by numerous lines of growth near the anterior margin of the shell, the shell having increased greatly in thickness without any proportionate increase in length.

Shells of this description occur in the Blanchester division of the Waynesville bed, near Clarksville, and Oregonia, Ohio, and near Roseburg, at Madison, and at the mouth of Bull Creek, in Indiana. A similar individual was found near the top of the bluff directly west of the wharf at Gore Bay, on Manitoulin Island (plate XI, Fig. 6).

Strophomena rugosa, Blainville

The following description of *Strophomena rugosa* was published by H. M. Ducrotay de Blainville in his *Manuel de Malacologie et de Conchiologie,* page 513, in 1825:

Animal tout-a-fait inconnu.

Coquille régulière symétrique, equilaterale, sub-equivalve; une valve plate et l'autre un peu excavée; articulation droite, transverse, offrant

à droite et à gauche d'une subéchancrure mediane, une bourrelet peu considérable, crénelé ou dentelé transversement; aucun indice de support.

Ex. *La Strophomene rugueuse, Strophomena rugosa,* Rafin., pl. LIII, fig. 2.

Observ. Ce genre, proposé par M. Rafinesque, ne contient encore que des espèces fossiles, au nombre des trois, suivant M. Defrance.

The following is a free translation:

Animal altogether unknown.

Shell regularly symmetrical, equilateral, with valves nearly equal in size; one valve flat and the other a little concave; hinge line straight, transverse, presenting, on the right and left of a sort of median V-shaped groove (formed by the hinge-areas), a small, moderately prominent elevation (the deltidium and chilidium), having a crenate or dentate outline when examined transversely; no indication of a means of support (pedicel).

The original figures were reproduced by Hall and Clarke in vol. VIII of the *Paleontology of New York,* page 247, in 1892. However, the copy of the pedicel valve presents only 72, instead of 92 radiating striae, and the postero-lateral angles are represented as more rectangular than in the original figure. Moreover, the figure of the brachial valve, showing also the hinge-area and deltidium of the pedicel valve, presents only 63 instead of 94 radiating striae, and fails altogether to show the distinct downward flexure of the marginal parts of the shell for a distance of fully 3 mm. from the anterior margin, and 2½ mm. from the lateral margin of the shell, as far back as the hinge-area, producing a geniculate downward depression of the shell all around the margin, beginning at an elevated concentric wrinkle, which is bordered posteriorly by a moderate concentric depression. The large size of the deltidium of the pedicel valve is brought out by Hall and Clarke's figure, but the lateral outlines of this deltidium are slightly convex instead of slightly concave.

In the *Dictionnaire des Sciences Naturelles,* vol. LI, page 151, published in 1827, Defrance gives the following description:

Strophomene rugueuse; *Strophomenes rugosa,* Rafinesque. Coquille bombée en dessous, et dont la valve supérieure est un peu concave et chargée de petites stries rayonnantes. Largeur, un pouce. Fossile de l'Amérique septentrionale. On voit une figure d'une coquille de cette espèce dans l'atlas de ce Dictionnaire, planche des fossiles. Des coquilles de ce genre, qu'on trouve à Dudley en Angleterre, ont de trés-grands rapports avec cette espèce; elles en different pourtant en ce que

le bord de celles d'Amérique se rétrousse un peu en dessous, tandis que c'est le contraire pour celles d'Angleterre, dont le bord s'abaisse en dessous. On trouve à l'ambouchure de la rivière des Alleghanys près de Pittsborough (Amérique septentrionale), dans un gres rougeatre, des empreintes de coquilles qui ont beaucoup de rapports avec cette espèce, mais qui sont plus aplaties.

The following is a free translation:

Shell with lower (brachial) valve convex and with upper (pedicel) valve a little concave, and covered with small radiating striae. Size, an inch. Fossil from North America. A figure of a shell belonging to this species may be seen in the set of plates accompanying this Dictionary, on the plate devoted to the illustration of fossils. The shells found at Dudley in England (*Strophonella euglypha*?) are closely related to this species. They differ chiefly in that the border of the lower valve bends up a little below (when the shell is placed with the brachial valve downward), while the contrary is true of the English specimens, whose border turns downward. (The last statement is not true, if the Dudley shell was *Strophonella euglypha*.) At the mouth of the Allegheny River near Pittsburg, in a reddish sandstone, casts of shells are found (*Derbya*?), which are closely related to this species, but are flatter.

If the interpretation given in the preceding translation is correct, these early writers were impressed more by the presence of a prominent deltidium than by the reversal of curvature of the shell, unless Defrance had some other shell in mind than the common Wenlock species, *Strophonella euglypha*. The chief reason for regarding *Strophomena rugosa* as a shell in which the general curvature of the brachial valve is convex are the figures accompanying the text, rather than the description.

The blunt truth, however, is that when it comes to the identification of the *species* originally described as *Strophomena rugosa*, this is pure guess-work, and the revival of this term, in the absence of any type specimens, or fuller subsequent description, or any knowledge of the locality from which it was obtained, is not to be recommended.

Strophomena neglecta, James[12]

(*Plate V, Figs. 1 A, B; 3 A, B, C, D, E, F; Plate VII, Fig. 5; Plate IX, Figs. 1 A, B, C; 10; Plate XI, Fig. 10*)

Strophomena neglecta was described by U. P. James from the upper or Blanchester division of the Waynesville bed, at a locality north of Second Creek, reached by going 1 mile west from Blanchester, Ohio, and then half a mile north. The collecting ground is east of the road, along a small branch entering Second Creek from the south. The lower *Hebertella insculpta* layer is exposed at the base of the section.

In the James collection, in the Walker Museum, at Chicago University, a series of specimens, numbered 2393, is labelled as types of *Strophomena neglecta.* Among these is the specimen represented by Figs. 1 *A, B,* on plate V, and Figs. 1 *A, B, C,* on plate IX of this Bulletin. This presents the normal aspect of the shell as far as the fineness and nearly equal size of the radiating striae, and the general curvature of the shell are concerned. The specimen is imperfect, however, anteriorly, and clay was moulded to it before photographing, the line of junction of which may be traced in the figures, especially 1 *B*. As a matter of fact, this attempted restoration was not very successful, and the outline should have been more nearly that shown by the right side of Fig. 3 *F*, on the same plate. It will be noted that in the case of Fig. 3 *F*, the left postero-lateral angle is almost rectangular, and shells with this subquadratic outline predominate. In the original description it was stated that *in some cases* the radiating striae vary *considerably,* and are irregularly arranged, from one to three or four of the smaller being placed between each two of the larger. The language used itself suggests that this type of ornamentation is not normal, as indeed it could not be, since it is characteristic of *Strophomena vetusta-precursor,* a shell occurring at the same horizon as *Strophomena neglecta,* and not recognized as clearly distinct by James, although he had described *Strophomena vetusta* himself, also from the vicinity of Blanchester, seven years earlier. The fact is that a moderate variation in the size of the striae, resulting in a grouping of finer striae among each pair of more prominent ones, is common, and

[12] *Paleontologist,* No. 5, p. 41, 1881.

the shells with the more conspicuous alternation of coarse striae with bundles of three or four finer striae were not readily distinguishable until the interiors of these shells were better known. Moreover *Strophomena vetusta* was established on a group of shells in which the nearly vertical wrinkling along the hinge-area was conspicuous, while in the earlier forms, here called *Strophomena vetusta-precursor*, this wrinkling is not always so conspicuous. Hence some specimens of the latter, for instance the one represented by Figs. 2 *A*, *B*, on plate V of this Bulletin, also appear among James's types of *Strophomena neglecta.* This has made possible the confusion in the interpretation of *Strophomena neglecta* shown by various authors, but a careful rereading of the original description, by one familiar with the conditions at Blanchester, and knowing the types, will readily verify the conclusion that James never intended to include in his *Strophomena neglecta* the Liberty and Whitewater species, *Strophomena vetusta,* in which the vertical wrinkling along the hinge-line is so characteristic. In reading this description by James, it should be remembered also that the term *Strophomena filitexta* was used by him for the specimens described and figured by Meek as that species, and not for the *Strophomena filitexta* of Hall, a species from a much lower horizon.

The type specimen illustrated by Figs. 1 *A* and *B*, on plate V of this Bulletin, presents the following characteristics. The greatest convexity of the brachial valve is 20 mm. from the beak; the thickness of the shell here is 6.8 mm. The valve is distinctly flattened posteriorly, especially within 15 mm. from the beak. Near the beak, the valve is slightly, but distinctly concave, the greatest concavity being 3 mm. from the beak. Hinge-area of the pedicel valve with a height of 3.8 mm. at the beak. The umbo anterior to the beak is most prominent about 4 mm. from the posterior margin of the shell, the general convexity of this part of the shell extending for about 13 mm. from this margin. Radiating striae of the brachial valve rather fine, every fourth, fifth or sixth stria slightly more prominent, about 13 or 14 striae occurring in a width of 5 mm. at a point 28 mm. from the beak. The striae on the pedicel valve are slightly more numerous and finer.

This specimen is the one referred to by Meek (*Paleontology of Ohio*, vol. I, page 85) when he states that one of the type speci-

mens of *Strophomena neglecta* was much more elongated on the hinge-line, and evidently had more acutely angular lateral extremities. He states, moreover, that all the type specimens have nearly the same sized striae, corroborating the view expressed above, that James did not intend to include shells of the type of *Strophomena vetusta* in his original description of *Strophomena neglecta*.

The muscular area of the pedicel valve of this species is large, forming about two-fifths of the width of the shell at the hinge-line. One of the chief diagnostic characteristics of the species is the presence of a series of radiate markings crossing the muscular area, resulting in a flabellate scar. The muscular area is traversed by a median ridge, which widens along the posterior half and bears the adductor scars. The outline of the muscular area is nearly circular, or sometimes more narrow and elliptical. The exterior edge of the border usually is abruptly elevated above the general surface of the interior of the valve, but the impressed muscular area rises rather gradually toward the anterior part of this border. Occasionally, the border rises only slightly above the general surface of the interior. In this case, the general surface of the interior of the shell is covered by numerous, minute papillae, arranged more or less parallel to the radiating striae seen on the exterior of the shell; and the shell is only slightly thickened toward the border. In specimens having a prominent border limiting the muscular area, the minute papillae are seen chiefly toward the margin of the shell, the parts surrounding the muscular area usually being covered with stronger, more or less radiating markings, which occasionally are broken up into irregular series of elongated papillae, similar to those identified as ovarian markings. The thickening of the shell toward the anterior and lateral margins of the interior usually is not conspicuous.

The interior of the brachial valve is marked by numerous minute papillae, except toward the muscular region, where they become larger. There is a tendency toward the arrangement of these papillae in more or less radiating rows. The adductor scars are distinctly limited posteriorly, but anteriorly their outline is rather vague. A triangular thickened area extends from the cardinal process forward, and then is extended across the adductor area as a low median elevation, disappearing near the anterior edge of the adductor area. The vascular ridges and sinuses,

usually extending forward from the muscular area toward the anterior margin of the shell, are either absent or relatively indistinct. The cardinal process is prominent, extending at right angles from the flattened area anterior to the beak. It is bi-lobed, and each lobe is grooved along the top, the grooves making angles of about 45 degrees with each other.

At the time the original description was published, nothing was known of the interior of the shell, and hence its description was based upon the appearance of the exterior. One of the chief characteristics of this part of the shell consists in the fineness and comparative equality in size of the radiating striae. At a distance of 30 mm. from the beak, the number of these striae varies from 12 to 15 in a width of 5 mm. Fifty millimeters from the beak, their number may equal only 8 or 9 in a width of 5 mm. The radiating striae on the pedicel valve are distinctly finer, compared with the more prominent striae on the brachial valve; in one case there were 15 striae in a width of 5 mm. while on the brachial valve there were 12 in the same width. Occasionally, the striae are distant from each other, and only 9 or 10 may be found in a width of 5 mm. at a distance of 30 mm. from the beak along the median part of the brachial valve. The radiating striae are crossed by much finer concentric striae, which usually are very distinct, under a magnifier, especially on the brachial valve.

Compared with other species at the same horizon, the shell of *Strophomena neglecta* is large and thin. Specimens 50 mm. in width, 40 mm. in length, and 15 mm. in convexity occur, but specimens 45 mm. in width, 35 mm. in length, and 12 mm. in convexity are more common. The flattened area anterior to the beak of the brachial valve extends for a distance of about 15 mm. from the hinge-area. The larger shells appear rather strongly and evenly convex when viewed from the side, the maximum curvature being about 20 mm. from the beak.

Compared with *Strophomena vetusta,* the hinge-area of the pedicel valve of *Strophomena neglecta* is more narrow; the brachial valve is more convex, and hence more deflected anterior to the postero-lateral angles; the flattened area of the brachial valve extends farther from the beak; the convexity anterior to the beak of the pedicel valve is more prominent and extends farther from the beak; the radiating striae of the brachial valve are finer; the vascular ridges and sinuses of the median parts of the brachial

valve usually are obsolete; the shell attains a larger size and is thinner, the interior of the pedicel valve not being conspicuously thickened toward the margin; and the muscular area of the pedicel valve is radiately striate or flabellate. The anterior terminations of the lateral borders of the muscular area are not deflected strongly to the front, on each side of the median anterior gap, as in the case of *Strophomena vetusta*.

Strophomena neglecta makes its appearance in the lower part of the Blanchester division of the Waynesville bed, either at the same time as *Strophomena nutans*, or a short distance above. The greatest vertical range is about 8 feet. At Owingsville, in Bath county, Kentucky, it occurs, associated with *Strophomena vetusta-precursor*, in a thin layer 12 feet below the *Dinorthis subquadrata* horizon. At Wyoming, in the southern part of Fleming county, it occurs 9 feet below the *Hebertella insculpta* horizon, which forms the base of the Liberty member. At Concord, in Lewis county, Kentucky, *Strophomena neglecta* occurs 15 feet below the *Hebertella insculpta* layer forming the base of the Liberty, and *Strophomena vetusta-precursor* comes in 4 feet above *Strophomena neglecta*.

The most southern exposure of the lower *Hebertella insculpta* horizon, at the base of the Blanchester division of the Waynesville member, is located almost directly south of the mouth of Gordon Run, along a road leading southward from Eagle Creek, about 5 miles west of West Union, in Adams county. Here *Catazyga headi* is abundant immediately above the lower *Hebertella insculpta* horizon. From this locality northwestward, *Strophomena neglecta* may be traced within the Blanchester division as far as the Narrows, east of the Pinnacles, and 4 miles southwest of Dayton, and then westward to the vicinity of Oxford, in the northwestern corner of Butler county. From the northern edge of Union county, in Indiana, to the vicinity of Brookville, in Franklin county, *Strophomena neglecta* occurs above the upper *Dinorthis carleyi* horizon, in strata also regarded as unquestionably belonging to the Blanchester division, since the upper *Dinorthis carleyi* horizon, in Ohio, belongs to the lower *Hebertella insculpta* zone, or immediately above. *Strophomena neglecta* is very common at Moores Hill, in Dearborn county. The most southern specimens occur north of Canaan, in the northern part of Jefferson county, 16 and 19 feet below the upper *Hebertella insculpta* horizon, which is located at the base of the Liberty member.

In the *Paleontology of Minnesota*, vol. iii, part 1, on page 388, Winchell and Schuchert refer to *Strophomena neglecta* a specimen from Savannah, Illinois. This specimen, from the Schuchert collection, is represented by Fig. 5 on plate VII of this Bulletin. The specimen is not distinct in any essential particular from an undoubted specimen of *Strophomena neglecta*, from Oregonia, Ohio, belonging to the Nickles collection. The latter (*Plate V, Fig. 3 B*) was figured because it was a narrow individual, presenting a somewhat triangular appearance, but the same features on the interior are presented by numerous other valves from the same locality, having the ordinary outline. A specimen similar to that from Savannah was found at the top of the hill immediately south of Kagawong, on Manitoulin Island (*Plate XI, Fig. 10*), in strata belonging a short distance above the *Hebertella insculpta* horizon, in the Richmond group. It is remarkable merely for being the only specimen of *Strophomena neglecta* discovered in a large series of *Strophomenas* found at essentially the same horizon at different localities on the island.

It is the presence of specimens of this type among the Richmond fossils of the Mississippi Valley which makes it desirable that *Strophomena planodorsata* be subjected to further study, on the basis of a much larger series of specimens than that at the service of the writer.

Strophomena neglecta is another of the species suggesting a connection between the Blanchester division of the Waynesville as exposed in Bath, Fleming and Lewis counties, in southwestern Ohio, and in Indiana as far south as Jefferson county, with the Richmond deposits in the Mississippi Valley by way of northern Illinois. By this is not meant an exact equivalency of the strata containing *Strophomena neglecta* to those containing *Strophomena planodorsata*, but at least an approximate equivalency.

Strophomena neglecta represents a reintroduction of the form of shell typified by *Strophomena incurvata*.

Strophomena vetusta-precursor, var. nov.

(*Plate X, Figs. 1 A, B, C; Plate V, Figs. 2 A, B, not the types*)

Typical specimens of *Strophomena vetusta* are abundant in the Whitewater bed. They are comparatively common in the Liberty bed, especially in the upper half. However, near the middle

of the Blanchester division of the Waynesville bed, the evident precursors of this species are not uncommon locally. Here they are associated with *Strophomena neglecta*. From the latter species they may be distinguished readily by the deflection of the lateral borders of the muscular area toward the front, leaving a median gap; by the tendency toward perpendicular wrinkling at the hinge-line; and by the irregular concentric wrinkling of the pedicel valve, accompanied by a corresponding deviation of the radiating striae from their usual straight-line directions.

Compared with the typical forms of *Strophomena vetusta*, from the Whitewater bed, the variety *precursor* usually has less prominent radiating striae on the brachial valve, even in cases where the number of striae is approximately the same. Frequently, however, the number of these striae equals 10 to 13, in place of 8 to 10, in a width of 5 mm. The area of the pedicel valve usually is not so conspicuously elevated, and the perpendicular wrinkling along the hinge-line usually is less in evidence. The four parallel ridges and intermediate vascular sinuses along the median parts of the interior of the brachial valve are less conspicuous. The interior of the valves is more minutely pustulose. In other words, the variety *precursor* differs but slightly from the typical Whitewater forms of *Strophomena vetusta*. The valves are thinner and less robust. Their chief interest lies in their earlier occurrence.

The types of the variety *precursor* were found in the Blanchester division of the Waynesville bed, along Penquite Run, two and a half miles west of Clarksville, Ohio, south of the pike, above the lower *Hebertella insculpta* horizon.

Strophomena vetusta-precursor occurs usually above the middle of the Blanchester division of the Waynesville member. It frequently is associated with *Strophomena neglecta*, especially in the lower part of its range, but at Moores Hill, in Dearborn county, Indiana; a mile and a half southwest of Oxford, in the northwestern part of Butler county, Ohio; at Oregonia, in Warren county; at Clarksville, in Clinton county; and at Concord, in Lewis county, Kentucky, its vertical range extends above that of *Strophomena neglecta*. At Moores Hill, its vertical range equals 11 feet, but usually it does not exceed 2 or 3 feet.

Its most southern range extends to Owingsville, in Bath county, Kentucky. Specimens are found also at Concord, in Lewis county; and on Eagle Creek, four miles west of West Union, in

Adams county, Ohio. It becomes more abundant northward, occurring in Stony Hollow, northwest of Clarksville, in Clinton county; also on Penquite Run, $2\frac{1}{2}$ miles southwest of Clarksville, in the eastern part of Warren county, and at Oregonia, in the same county. In Greene county, it occurs a mile northwest of Mount Holly, and a mile southeast of Bellbrook. In Montgomery county, it occurs at the Narrows, east of the Pinnacles, 4 miles southeast of Dayton; at Miamisburg; and a mile and a half southwest of Farmersville, where the road follows Twin Creek, in the northern edge of German Township. In Preble county, *Strophomena vetusta-precursor* occurs about a mile and a half northeast of Gratis, on Twin Creek; in Butler county, a mile and a half southwest of Oxford; in Dearborn county, Indiana, it occurs east of Weisburg, and much more abundantly, east of Moores Hill.

It is very probable that it is fairly common within most of the area here indicated, but the species has not been differentiated readily from *Strophomena neglecta* until recently, and is not often mentioned in the field notes.

Strophomena vetusta makes its first appearance in the Blanchester division of the Waynesville under the form of its variety *precursor*. Here it is distributed from Lewis county in Kentucky westward across southwestern Ohio to Dearborn county in Indiana. During the Liberty and Whitewater, its range was much more extended, reaching Nelson and Madison counties, in Kentucky. It is not known from any part of the Mississippi Valley Richmond or from the borders of Lake Huron or the vicinity of Toronto. As in the case of *Strophomena concordensis* and its related species, and also in the case of *Strophomena planumbona*, as far as its range in Ohio, Indiana, and Kentucky is concerned, *Strophomena vetusta* appears first in lower strata northward and then spreads later over a greater area southward. Since the same feature is shown also by *Strophomena sulcata*, the evidence seems to favor a northern basin, probably occupying a considerable part of Ohio and Indiana, probably more or less frequently cut off from the Mississippi Valley basin, within which a more or less characteristic Richmond fauna was developed and from which the fauna migrated at various times to varying distances southward. At times the connection with the Mississippi Valley basin may have been fairly good; for instance, at the beginning

and close of the Blanchester division, during the ingression of *Hebertella insculpta;* also early in the Liberty, during the ingression of *Dinorthis subquadrata;* probably also during the middle of the Blanchester, during the ingression of *Strophomena neglecta,* and later, during the ingression of *Austinella scofieldi.* During the greater part of the Liberty, however, and during all of the Whitewater, this basin in Ohio and Indiana appears to have been entirely cut off from the Mississippi Valley Richmond seas.

Strophomena vetusta, James[13]

(*Plate VI, Figs. 2 A, B, C, D, E, F, G, H*)

The muscular area of the pedicel valve equals in width about one-third to two-fifths of the width of the shell. Postero-laterally, the muscular area is abruptly limited by a sharply ascending border. Antero-laterally, the surface of the area rises more gradually toward the border, and here the limiting border may rise sharply above the general surface of the interior of the valve, or only the outer slope of the border may be sharply defined. The surface of the muscular area is not conspicuously striated in a radiate or flabellate manner, as in *Strophomena neglecta.* Anteriorly, the lateral border is deflected forward, leaving a rather broad median gap, which is one of the characteristics of this species. A rather narrow median ridge, widening only slightly posteriorly, indicates the line of attachment of the adductor muscles. The deflected anterior terminations of the lateral borders of the muscular area are extended anteriorly as ridges, between which one or two additional ridges may appear, the various ridges being separated by the vascular sinuses. These ridges and intermediate grooves are much less distinct than those on the median parts of the brachial valve, and usually extend only about half way from the muscular area toward the anterior margin of the valve. The shell usually is only moderately thickened along the anterior and lateral edges.

The interior of the brachial valve is marked by four strong parallel ridges with the intermediate vascular sinuses. Posteriorly, they terminate within the diductor area, the two inner ridges having a tendency to unite with the median elevation

[13] *Cincinnati Quarterly Journal of Science,* vol. i, p. 241, 1874.

extending forward from the thickened portion of the shell beneath the cardinal process. The interior of the brachial valve is marked by irregular, elongated papillae or short ridges, which become coarser toward the vascular markings and toward the posterior parts of the shell, but are finer toward the lateral and anterior margins. Their arrangement usually is very irregular. Similar markings are found on the interior of the pedicel valve. They give a roughened or shagreen effect to the surface of the interior.

The most characteristic features of the exterior of the shell are the high hinge-area; the usually conspicuous wrinkling of the posterior part of the shell, approximately perpendicular to the hinge-line; the very fine radiating striae on the pedicel valve, and the much coarser striae on the brachial valve. In a shell 33 mm. wide, the height of the hinge-area of the pedicel valve may equal 4 or 5 mm. at the beak. In some of the thicker specimens, the height of this hinge-area may be fully 1.7 mm. within 2 mm. of the lateral terminations of the area. The wrinkling of the posterior part of the valves, perpendicular to the hinge-area, extends only a short distance from the area near the beaks, the extent of the wrinkling increasing toward the postero-lateral angles of the valves, sometimes involving the shell to a distance of 5 or 6 mm. from the hinge-area. The number of radiating striae on the pedicel valve frequently equals 18 to 21 in a width of 5 mm., 25 mm. from the beak, but may be as low as 14 in the same width. Occasionally, every fourth one of these striae is slightly more prominent. Usually the radiating striae are crossed by a set of irregular concentric wrinkles and fine striae, accompanied occasionally by somewhat squamose lines of growth, rather irregular at the edges; moreover, the radiating striae tend to change more or less in direction, especially toward the anterior and lateral margins of the valves. The result is a peculiar irregular appearance of the markings on the exterior of the pedicel valve which is very diagnostic of this species. The number of radiating striae on the brachial valve equals 8 to 10 in a width of 5 mm. at 25 mm. from the beak. Toward the beak, every second or fourth striation may be more prominent, but anteriorly the striae are more nearly of the same size, or alternate in part, the intermediate striae being comparatively inconspicuous. The two valves differ greatly in the coarseness of their striations.

The shells may attain a width of 40 mm. The length of the

larger specimens may vary from 26 to 30 mm. The postero-lateral outlines are either rectangular or slightly extended along the hinge-line. The brachial valve is almost evenly convex, the flattening at the beak being inconspicuous. In a corresponding manner, the concavity of the pedicel valve is comparatively uninterrupted at the beak, the convexity immediately anterior to the beak usually being inconspicuous. The convexity of the brachial valve equals 8 mm. in shells 33 mm. in width.

In the original description, the type specimens are stated to have come from the upper part of the Cincinnati group, in Ohio and Indiana. In the James collection, preserved in the Walker Museum, at Chicago University, a series of specimens, numbered 1567, is labelled as forming the types of *Strophomena vetusta,* and as coming from Blanchester, Ohio. An examination of these specimens suggests that they are characteristic Liberty or Whitewater forms, and not the form from the Blanchester division of the Waynesville bed, here called *Strophomena vetusta-precursor.* Of these types, four are illustrated by Figs. 2 *B, C, D,* and *E,* on plate VI of this Bulletin.

The first appearance of *Strophomena vetusta* is in the Blanchester division of the Waynesville, where it bears the name *Strophomena vetusta-precursor,* and where the valves are distinctly thinner than in the more typical specimens, found in the Liberty and Whitewater beds. At those localities at which *Strophomena planumbona,* or *Strophomena planumbona-subtenta,* is very abundant in the lower part of the Liberty, *Strophomena vetusta* comes in near the middle of the Liberty and does not become abundant until the upper part of the Liberty is reached. This appears to be true at Concord, Kentucky, and near Clarksville, Camden, and elsewhere in Ohio. In the Whitewater bed, however, it ranges from the base to the top.

On the eastern side of the Cincinnati geanticline, *Strophomena vetusta* has been identified with certainty as far southward as Wyoming, in the southern part of Fleming county, and with considerable probability as far as College Hill, in the northeastern part of Madison county. From Wyoming southward, its vertical range appears to be in the Liberty. Northward, in Ohio and Indiana, it occurs also in the Whitewater bed.

On the western side of the Cincinnati geanticline, in Kentucky, *Strophomena vetusta* can be traced as far southward as Bardstown,

and a locality 4 miles east of Bardstown, in Nelson county, in the Liberty member. If the fossiliferous strata overlying the Saluda are to be regarded as Whitewater, then *Strophomena vetusta* occurs in the Whitewater as far south as the northwestern corner of Ripley county, and the southern part of Decatur county. Farther northward, in Indiana and Ohio, it is abundant at the Whitewater horizon.

Strophomena vetusta is found occasionally in the lower part of the Saluda member, above the *Columnaria* horizon, in Jefferson and Ripley counties, in Indiana.

Strophomena vetusta-approximata, James[14]

(*Plate VI, Figs. 1 A, B, C, D*)

Strophomena approximata was described by U. P. James from the upper part of the Cincinnati group, in Dearborn county, Indiana. Two specimens, numbered 2394, and labelled *Strophomena approximata,* occur in the James collection, preserved in the Walker Museum, at Chicago University. These are illustrated in this Bulletin. The larger specimen was used for the original description by James. An examination of the types indicates that they are very closely related to *Strophomena vetusta,* and differ only in outline. The specimens are subtriangular, rather than subquadratic in outline. Specimens of this type are very rare, and occur only as isolated individuals at distant localities, and only where *Strophomena vetusta* is abundant. Apparently these triangular specimens are to be regarded merely as pathological variations from *Strophomena vetusta,* and not as varieties tending toward the formation of a new species. The types have the appearance of specimens from the Whitewater bed, but there is also a possibility of their having been obtained in the Liberty bed, and the latter is exposed at Moores Hill, at Weisburg, and at other localities in the northwestern part of Dearborn county, in Indiana. The brachial valve of the type of *Strophomena vetusta-approximata* is flattened for some distance anterior to the beak. The length of the shell is 3.2 mm., and the greatest convexity equals 10.3 mm. at 18.5 mm. from the beak. The thickness of the shell at this point is 4.1 mm. The width of the shell

[14] *Paleontologist,* No. 5, p. 43, June 10, 1881.

along the hinge-line is 4.5 mm. The height of the hinge-area is 5.3 mm. The radiating striae of the brachial valve are rather coarse, one or two finer striae occurring between some of the coarser ones. At 25 mm. anterior to the beak, about 10 of the coarser striae occur in a width of 5 mm. Radiating striae of the pedicel valve distinctly finer and more numerous, about 15 in a width of 5 mm., at a point 25 mm. from the beak, not counting the finer intercalated striae. Posterior half of the pedicel valve concentrically wrinkled. Hinge-area broadly triangular, 5.3 mm. in height at the beak.

Strophomena sulcata, Verneuil[15]

(*Plate I, Figs. 4 A, B, C; Plate XI, Figs. 2 A, B*)

Strophomena sulcata was described by de Verneuil in the *Bulletin Société Géologique de France,* vol. V, page 350, in 1848. Figs. 4 *a*, and 4 *b*, on plate IV, accompanying the original description, suggest the presence of rather coarser radiating striae than those typical of the Richmond species usually identified as *Strophomena sulcata*; the height of the hinge-area of the pedicel valve, as figured, is too great, the anterior outline of the shell appears too incurved for a specimen exhibiting the hinge-area well, and the lateral outlines of the shell are not those most common, although occasionally found. De Verneuil's collection at present is located at the École des Mines, at Paris. Neither *Strophomena sulcata* nor *Protarea verneuili* can be found there. The types apparently have been lost. However, the reference to the conspicuous sinus of the valve at present called the pedicel valve, and the statement that *Strophomena sulcata* is found in the blue limestone of Ohio and Indiana, are sufficient to indicate that the Richmond species was being described. *Strophomena sinuata* is so very rare in Indiana, that it is extremely unlikely that this species was obtained by de Verneuil from that state. *Strophomena sulcata,* as identified from the Richmond, however, is common at several horizons in both states, and always attracts the attention of collectors.

Shells small; width usually varying between 18 and 23 mm., rarely equalling 30 mm. Ratio of length to width usually between 0.67 and 0.75, but it may be as low as 0.61 and as high as 0.80.

[15] *Bulletin, Société Géologique de France,* vol. v, p. 350, 1848.

Hinge-line usually approximately equal to or only slighter longer or shorter than the width of the shell across the middle, the lateral margin meeting the hinge-line nearly at right angles. Occasionally, the length of the hinge-line exceeds the middle width of the shell conspicuously, and the lateral margins of the shell may meet the hinge-line at angles as low as 63 degrees.

Brachial valve flat at the umbo, usually raised anteriorly along the median line so as to form a more or less prominent median elevation. Shell usually nearly straight or only slightly convex from front to rear along this median elevation, especially when the latter is prominent.

Pedicel valve moderately convex near the beak, more or less depressed anteriorly, forming a shallow median sinus along the anterior half of the valve.

Radiating striae within a distance of 1 cm. from the beak usually between 50 and 55, but occasionally as few as 45 or as many as 70 in number. When the striae are numerous the primary striae are not conspicuously larger than the secondary. However, when the striae are less numerous, the former often are so much more conspicuous that the shell appears rather coarsely striated. In extreme cases the shells are striated almost as coarsely as in typical specimens of *Strophomena sinuata.* If de Verneuil's statement, that *Strophomena sulcata* occurs along with *Strophomena planoconvexa,* were taken literally, then the coarseness of the striations in his figures would be readily accounted for, since the radiating striations of *Strophomena sinuata* are typically coarser.

Average specimens of *Strophomena sulcata* may be readily distinguished from *Strophomena sinuata* by the stronger median elevation and depression, by the straightness or moderate convexity of the brachial valve from front to rear along the median line, and by the less coarse or decidedly finer radiating striae.

In shells having the more numerous and finer radiating plications, the median elevation and depression often are but slight; in some cases even less than in typical specimens of *Strophomena sinuata.* When these features are accompanied by a conspicuous elongation of the shell along the hinge-line, so that the lateral margins form acute angles with the latter, the shells differ conspicuously from the more typical quadrate forms of *Strophomena sulcata.* However, the transversely elongate forms occur only

in association with those having quadrate outlines, and both are connected by so many intermediate forms, that they are not distinguished here even as varieties.

The muscular area of the pedicel valve equals about three-tenths of the width of this valve. Postero-laterally it is distinctly bounded by a sharp border extending forward from the teeth; laterally, this border rapidly diminishes in height; and along the anterior margin of the area there usually is no trace of the border. A rather faint median line of elevation, widening posteriorly, traverses this area and indicates the line of attachment of the adductor muscles. In the interior of the brachial valve, the two lobes of the cardinal process, the divergent crural plates, and the median ridge extending forward from the callosity immediately in front of the cardinal process, are well developed, considering the size of the shell. The median ridge, mentioned above, terminates at the anterior end of the adductor areas. Sometimes the adductor areas are clearly defined anteriorly, but frequently there is only a rather vague suggestion of this outline. The vascular ridges and sinuses found along the median parts of the brachial valve in other species of *Strophomena*, usually are imperfectly indicated or absent. The location of the radiating striae ornamenting the exterior of the shell frequently can be detected on the interior. Aside from the markings already described, the general surface of the interior is smooth, or is covered by minute papillae seen only under a magnifier.

In Stony Hollow, northwest of Clarksville, in Clinton county, Ohio, *Strophomena sulcata* is seen at the very base of the Clarksville division of the Waynesville member, immediately above the *Orthoceras fosteri* clay bed. From this horizon, it ranges upward a distance of 7 feet, and is fairly common in several layers. Most of the specimens are distinctly sinuate anteriorly, as the name suggests, and the radiating plications of most specimens are rather coarse, a fact which is true also of the specimens found at the lower *Hebertella insculpta* horizon. Occasionally, however, specimens are found in which these plications are about as numerous as in the Liberty and Whitewater forms.

About 1 foot above the base of the Clarksville division, in Stony Hollow, northwest of Clarksville, brachial valves of *Strophomena sulcata* occur, which are almost evenly convex. Some of these specimens are 24 mm. wide. In that case they bear some resem-

blance to the brachial valves of *Strophomena planoconvexa*. The pedicel valves of these specimens are unknown, and there is no reason as yet for regarding them as anything more than aberrant individuals of *Strophomena sulcata* in which the sinuate flexure of the anterior half of the shell failed to develop.

A mile and a half southwest of the railroad station at Fort Ancient, in Warren county, Ohio, *Strophomena sulcata* ranges from 1 to 4 feet above the *Orthoceras fosteri* clay layer.

East of Moores Hill, in the western part of Dearborn county, Indiana, *Strophomena sulcata* also occurs in the lower part of the Clarksville division, over strata containing *Strophomena planumbona*. Both *Strophomena sulcata* and *Strophomena planumbona* have an extended vertical range in the Richmond, and both are seen first in the lower part of the Clarksville division, but *Strophomena sulcata* appears to have arrived a little later.

Strophomena sulcata recurs at the lower *Hebertella insculpta* horizon, at the base of the upper or Blanchester division of the Waynesville bed. It occurs at this horizon at Stony Hollow, northwest of Clarksville, also along Sewell Run, southeast of Clarksville, and along Second Creek, northeast of Blanchester, in Clinton county, Ohio. It occurs at the same horizon along the creek 1½ miles southeast of Fort Ancient, in Warren county; half a mile south of Mount Holly, in the northern part of Green county; at Miamisburg, in Montgomery county; and along Dry Fork of Elk Run, 1¼ miles south of Jacksonburg, in the northern part of Butler county, Ohio. At Concord, in Lewis county, Kentucky, it occurs 18 feet below the upper *Hebertella insculpta* horizon, or 3 feet below the *Strophomena neglecta* layer. This should place it near the base of the Blanchester division.

In the Liberty member, *Strophomena sulcata* occurs in Clinton county, Ohio, at various levels between the base and top. West of Camden, in Preble county, it occurs in the lower part of the Liberty, and it is found in the same position also at Concord, in Lewis county, Kentucky. Westward, it occurs apparently at least as far as Madison, in Jefferson county, Indiana.

In the Whitewater member, *Strophomena sulcata* occurs in Clinton county, Ohio, at various levels from the base to the top. While abundant also at other levels, it has been noted especially near the top of the Whitewater member, from Clinton county, Ohio, as far south as the locality west of Spencer in Montgomery

county, also the one west of Indian Fields, in Clark county, and the one east of College Hill, in Madison county, all in Kentucky. Northward, in Ohio, it occurs at the top of the Whitewater as far as Dayton, in Montgomery county, and thence, westward, at various localities in Preble and Butler counties, as far as Richmond, in Indiana.

If the fossiliferous strata overlying the Saluda bed in Ripley, Decatur, and Jennings counties, in Indiana, are to be regarded as of Whitewater age, then *Strophomena sulcata* may be traced at this horizon as far westward as Decatur county, and as far southward as the locality about 2½ miles south of Versailles, in Ripley county.

If the fossiliferous strata immediately below the Saluda member, in western Kentucky, are to be regarded as Liberty, then *Strophomena sulcata* may be traced at this horizon as far south as the localities east of Jeffersontown and near Mount Washington, in Jefferson county; those in the eastern part of Bullitt county; east of Bardstown, in Nelson county; and east of Raywick, in the southwestern part of Marion county.

In the Saluda member, *Strophomena sulcata* occurs at Madison, Indiana, 7 feet above the great *Columnaria* horizon, which here forms the base. West of Weisburg, in the northwestern part of Dearborn county, it occurs near the middle of the section which here intervenes between the so-called shale layer near the base and the typical mottled limestone, which forms the top of the Saluda section.

Strophomena sulcata is not known, at present, from the Elkhorn member.

From these data it appears that *Strophomena sulcata* has a vertical range from the base of the middle or Clarksville division of the Waynesville member to the top of the Whitewater member of the Richmond.

The most southern locality known at present at which *Strophomena sulcata* occurs is north of Dismukes Station, in Sumner county, Tennessee. Here it is found associated with *Rhynchotrema dentata*, *Leptaena richmondensis*, *Strophomena planumbona*, and other fossils, at a horizon probably near the upper or Blanchester division of the Waynesville bed. The nearest exposure in Kentucky, containing *Strophomena sulcata*, is located in the northeastern corner of Raywick, in Marion county, 95 miles

distant. At the latter locality, this fossil occurs at the southern limit of extension of the *Dinorthis subquadrata* and *Strophomena vetusta* fauna, these fossils occurring at Bardstown and other localities in Nelson county, farther northward. The horizon is regarded as about equivalent to the Liberty member of the Richmond, and as above the horizon of the *Strophomena sulcata* fauna at Dismukes Station. The nearest known locality of *Strophomena sulcata* at the Blanchester horizon probably occurs in southern Indiana, near Madison.

In the Richmond on Manitoulin Island, *Strophomena sulcata* occurs at various levels between the *Hebertella insculpta* horizon and the rich coral bed, 40 or 50 feet farther up. It occurs at this horizon at Little Current, Kagawong, and Gore Bay. The strata are regarded as approximately equivalent to the Blanchester division of the Richmond.

Geographically, *Strophomena sulcata* makes its first appearance near the base of the middle or Clarksville division of the Waynesville, in Ohio and Indiana. It may have had an equally great distribution near the base of the upper or Blanchester division, but at present it is definitely known at this horizon only in a rather restricted area in southwestern Ohio. The fact that it occurs also at the Waynesville horizon near Gallatin, in northern Tennessee, is in favor of its migration from some region accessible to both areas. Judging from the discoveries on Manitoulin, this Waynesville sea extended to the northern edge of Lake Huron. In the Liberty sea, *Strophomena sulcata* ranged as far south as Concord, on the Ohio River in eastern Kentucky, and to Raywick, in Marion county, in western Kentucky. In the Whitewater sea, its range extended as far south as Madison county, in eastern Kentucky, and as far as Ripley county, in Indiana.

On the accompanying chart (plate XVIII), the range of *Strophomena sulcata* during the Waynesville is indicated by the areas crossed by diagonal lines. Its range during the Liberty and Whitewater is indicated by the much more extended area enclosed by the dotted line. Its range at the lower *Hebertella insculpta* horizon, at the base of the Blanchester, appears to have been more restricted than earlier, during the Clarksville period of deposition, although the species appears to be more constant in its occurrence at the base of the Blanchester than at the lower horizons.

Strophomena sulcata is most abundant in the Liberty and Whitewater, especially near the top of the Whitewater.

Owing to the absence of *Strophomena sulcata* from the Richmond of the Mississippi Valley, with the possible exception of a limited area in southern Illinois, it is another species, suggesting perhaps an indigenous origin in some basin including Ohio and Indiana.

Strophomena cardinalis, Whitfield[16]

The chief characteristics of *Strophomena cardinalis* it shares with *Strophomena wisconsinensis,* described from the same horizon and locality. These characteristics are the high hinge-area, nearly parallel with the flattened posterior part of the brachial valve, the relatively large convex area anterior to the beak, and the rather strong downward deflection of the brachial valve anterior to the flattened area. The reversal in the curvature of the pedicel valve from convex to concave is only slight, and takes place so near the anterior margin as to suggest that the types of this species were immature shells. Opposed to this view is the great height of the hinge-area in specimens of comparatively small size. In the figured specimen, the width of the shell is 22 mm.; the length 17 mm.; and the height of the hinge-area, nearly 4 mm. In general, the height of the hinge-area is nearly one-fifth of the length of the shell. In form, the area is conspicuously triangular. Richmond group, at Delafield, Wisconsin.

It is a suspicious circumstance that *Strophomena cardinalis* does not reappear in the collections made, since this species was described, at Delafield, and at other localities containing strata belonging to the same horizon.

Strophomena wisconsinensis, Whitfield[17]

(*Plate VII, Figs. 1 A, B, C; Plate IX, Figs. 5 A, B, C*)

The types were obtained from the Richmond beds at Delafield, Wisconsin. Their most characteristic feature is their great convexity. The brachial valve is highly arcuate and gibbous near the middle, the greatest convexity being at the middle

[16] *Geology of Wisconsin,* vol. iv, 1882, p. 261, Plate XII, Figs. 9, 10.
[17] *Geology of Wisconsin,* vol. iv, p. 263, 1880.

or even posterior to the middle of the valve. The posterior part of the valve is distinctly flattened, and the part immediately anterior to the beak is slightly concave. The pedicel valve is rather deeply concave, although distinctly convex near the beak.

These characteristics are possessed by the three specimens from the Richmond group at Wilmington, Illinois, figured in this Bulletin, all from the Schuchert collection. The hinge-area of the pedicel valve is rather high and is approximately parallel to the flattened surface of the brachial valve. This feature is best seen when the shell is viewed from the side. The muscular area of the pedicel valve is subcircular. The limiting lateral ridges rise prominently above the body cavity; they are not strongly deflected toward the front anteriorly. Vascular markings extend radially toward the anterior margin of the valve. They are distinct even 10 mm. back from this margin, and the shell is only moderately thickened within the area traversed by them. The radiating striae are about as fine as those of *Strophomena planumbona*, or slightly coarser.

Compared with *Strophomena concordensis*, the brachial valve is more gibbous, the hinge-area of the pedicel valve is higher, and it is more nearly parallel to the flattened posterior part of the brachial valve.

Strophomena planodorsata, Winchell and Schuchert[18]

(*Plate VII, Figs. 4 A, B; 6; 7 A, B; 8; Plate IX, Figs. 6 A, B; 7; 8 A, B; 9; 11; 12; 14 A, B*)

The figures of the type, from the Richmond group at Spring Valley, Minnesota, are reproduced as Figs. 6 *A*, *B*, on plate IX, of this Bulletin. The chief feature of this shell consists in its large size, subquadrate outline, and fine surface striation. The flatness of the brachial valve for more than half its length is very unusual in specimens of this large size and is well described by the term *planodorsata*. In a similar manner, the pedicel valve is only slightly concave for more than half its length, then curves up rapidly toward the anterior and lateral margins.

Compared with this shell, the flattened area on the posterior half of the brachial valve of *Strophomena neglecta* certainly is less

[18] *American Geologist*, vol. ix, p. 286, 1892.

extensive, and if this be a constant specific difference, it warrants the separation of *Strophomena planodorsata* from that species.

It is doubtful, however, whether the extensive flattening of the posterior part of the brachial valve in the type of *Strophomena planodorsata* will prove even a fairly constant specific feature. A number of large specimens, apparently identical with typical *Strophomena planodorsata*, occur in the T. E. Savage collection from the Fernvale limestone at Thebes, Illinois, but the specimens are all pedicel valves. These valves have about the same curvature as that indicated for the pedicel valve of the type in Fig. 6 A on plate IX. The valves vary in length from 35 to 40 mm., the reversal of the curvature begins at 20 mm., but becomes distinct at 25 mm. from the beak. The number of radiating striae varies from 7 to 8 in a width of 2 mm., where not increased by implantation of intermediate striae. It is probable, however, that the brachial valve has a much more pronounced curvature and is ornamented by distinctly coarser striae than those on the pedicel valve.

Various specimens, from the Richmond group at Wilmington, Illinois, have been identified by Schuchert with *Strophomena planodorsata*. Some of these present views of the interior of the pedicel valve. One specimen was used for Fig. 10, on plate XXXI, of the *Minnesota Geological Survey*, vol. III, part 1, and the same specimen, belonging to the Schuchert collection, is illustrated by Fig. 6 on plate VII of the present Bulletin. The height of the hinge-area in this specimen is 4.2 mm. The muscular area is nearly circular, and is characterized by flabellate markings separated by a single distinct median ridge. The interior of this area rises gradually toward the limiting ridge, which descends abruptly into the body cavity. Posteriorly it approaches the hinge-line exterior to the teeth. The curvature of this valve is indicated by Fig. 7 on plate IX.

Similar interiors of pedicel valves of equal size, from the Fernvale limestone at Wilmington, Illinois, collected by Prof. T. E. Savage, indicate that the narrow thickened border, along the anterior and lateral margin of the pedicel valve figured by Schuchert, is not a constant feature, and usually is absent. Instead, there is a moderate thickening of the interior, with its maximum between 5 and 7 mm. from the margin, fading away posteriorly. This thickened area is crossed by rather incon-

spicuous radiating vascular markings. The muscular area is large, compared with the size of the valves, but the postero-lateral border of this area does not join the hinge area farther exterior to the teeth than in many a specimen of typical *Strophomena neglecta* from Ohio and Indiana. One brachial valve is flattened for 20 mm. posteriorly, and then is strongly deflected downward at about 80 degrees for a distance of 30 mm., the direct length of the shell being 40 mm. Evidently, strong curvatures are to be expected in some of the shells, anterior to the flattened posterior area, in *Strophomena planodorsata.* The radiating striae were subequal or alternated in size, about 7 or 8 occuring in a width of 2 mm. On a brachial valve from the same locality, belonging to the Schuchert collection, there are 15 subequal radiating striae in a width of 5 mm. near the anterior margin. Over the flattened area near the middle of the valve, some of the striae are more prominent, and are separated by 3 to 5 finer ones.

Two specimens of smaller size, from the Richmond beds of Wilmington, Illinois, also belonging to the Schuchert collection, are illustrated by Figs. 7 *A*, *B*, on plate VII, and Figs. 8 *A*, *B*, and Fig. 9 on plate IX of this Bulletin. On the flattened area of the brachial valve certain striae are slightly more prominent, and are separated from each other by 4 or 5 finer striae. Anterior to the flattened area, the striae become more nearly equal in size, about 19 or 20 occupying a width of 5 mm. along the anterior margin. The pedicel valve has a circular muscular area with flabellate markings. The margin of this area is scarcely raised above the general surface of the body cavity. At the hinge-line the area is better defined, but here the border does not meet the hinge-line distinctly exterior to the teeth. Possibly this border moves outward with increased maturity of the shell. The greatest convexity of the complete but somewhat crushed shell, 16 mm. from the hinge-line, is 10 mm. Height of the hinge-area of the pedicel valve, 4 mm. The shell is 26.5 mm. long, and the flattening of the brachial valve extends for a distance of about 15 mm. from the beak.

With these smaller forms of *Strophomena planodorsata* from Wilmington, Illinois, I have identified some specimens from the Richmond beds in western Tennessee. About 17 radiating, subequal striae occupy a width of 5 mm. Specimens with the flat-

tening of the brachial valve extending for more than half the length of the shell from the beak were noticed at Clifton, and near the home of W. D. Helton, on Beech Creek, 3 miles northwest of Waynesboro. Others, with the flattening extending only as far as the middle, were seen at Riverside, and along Leipers Creek in Maury county, north of Fly's store. A specimen from the last locality is illustrated by Figs. 4 *A*, *B*, on plate VII and Figs. 14 *A*, *B*, on plate IX of this Bulletin.

A pedicel valve from Iron Ridge, Wisconsin, forming No. 8191 of the University of Minnesota collection, is illustrated by Fig. 8 (magnified) on plate VII of this Bulletin. The muscular area resembles that of Fig. 7 *A* on the same plate. The interior of the body cavity is marked by minute granules arranged in radiate lines, about 35 in a width of 5 mm. These granules are characteristic of the species. The valve is very flat, and is very moderately curved at the anterior end.

Excepting in the outline of the shell, the last specimen closely resembles the specimen of *Strophomena neglecta* from Oregonia, Ohio, illustrated by Fig. 3 *A*, on plate V. The latter specimen presents the same flabellate scar, scarcely rising above the body cavity at the border, and also the numerous minute granules arranged more or less in radiating series. Other specimens of *Strophomena neglecta* occur which resemble the larger valve of *Strophomena planodorsata* illustrated by Schuchert from Wilmington, Illinois (illustrated also by Fig. 6, on plate VII, of this Bulletin). In fact, the interiors of *Strophomena neglecta* vary considerably, but all agree in having flabellate muscular areas, and numerous small granules more or less arranged in radiating lines, but the size of these granules varies considerably.

The prominence of the border surrounding the muscular area of the pedicel valve is not of diagnostic value. This feature varies considerably in different individuals of the same species. Typical specimens of *Strophomena planodorsata* from the Fernvale at Wilmington, Illinois, often have prominent borders, while in a suite of specimens from Sterling, Illinois, regarded as *Strophomena neglecta*, this border varies from fairly prominent to as low as in the specimen here figured from Iron Ridge. In these specimens from Sterling, the shell usually is about 27 mm. long, 40 mm. wide at the hinge-line, and only 35 mm. wide about 9 mm. in front of hinge-area. There are 11 or 12 sub-

equal striae in a width of 5 mm., or 7 or 8 stronger striae with enough intermediate narrower ones to give a total of 15 striae in this width. On the pedicel valve, the number of striae equals 17 subequal in a width of 5 mm., or 15 stronger ones with sufficient finer ones to give a total 19 or 20 in the same width.

There is no doubt that *Strophomena planodorsata* represents the western variant of *Strophomena neglecta.* Whether the species are to be regarded as essentially distinct must be determined from a much larger series of specimens than those which I have had the privilege of examining. Considering the distance between the area within which *Strophomena planodorsata* has been identified, and that in Indiana, Ohio, and adjacent Kentucky, within which *Strophomena neglecta* abounds, there is a probability of their being at least geographical variants, belonging to partially separated epicontinental oceanic basins.

Strophomena fluctuosa-occidentalis, nom. nov.[19]

(*Plate IX, Figs. 17 A, B, C, D; Plate X, Figs. 9 A, B, C, D, E*)

The species described by Winchell and Schuchert from Spring Valley, Minnesota, is a much smaller form than that figured by Billings under *Strophomena fluctuosa,* nor has it the greatly extended hinge-line. The wrinkles are concentric and are confined to the posterior flattened area of the valves; they are more or less conspicuously interrupted where they are crossed by the more prominent radiating striae. The latter alternate, at the geniculate deflection, with 7 to 11 much finer and quite inconspicuous striae. At the beginning of this deflection, the median one of the finer striae becomes conspicuous, and, farther down the slope of the deflection, the median striae of the secondary groups of finer striae become conspicuous in turn, especially along the median parts of the shell, so that along the border of the nasute part of the shell, and sometimes also laterally, there is an alternation of stronger striae with only one, two, or three finer ones.

The most characteristic feature of the brachial valve is the relatively great height of its hinge-area, considering the small size of the shell. This height equals about 1 mm. in shells having a width of 20 mm. The posterior part usually is conspicuously

[19] *Minnesota Paleontology,* vol. iii, part 1, Plate XXXI, Figs. 14–17, 1893.

flattened, with a moderate concavity toward the beak. The strong downward deflection anteriorly and laterally takes place from 10 to 11 mm. from the beak; and the anterior slope of the valve frequently reaches a length of 13 to 20 mm. In that case the shell has a triangular, or subpentagonal, nasute outline. The upper faces of the lobes of the cardinal process are flat, resting upon a callosity which extends laterally to the inner sides of the sharp crural plates, and anteriorly merges into the conspicuous median ridge separating the rather deeply impressed adductor scars. No conspicuous vascular ridges and sinuses were noticed anteriorly along the median parts of the shell, but distinctly defined grooves throughout the interior of this valve indicate the location, exteriorly, of the more prominent radiating striae.

Deltidium of the pedicel valve less conspicuous than usual on account of the strongly developed chilidium of the brachial valve. The hinge-area is fairly high, the hinge-teeth are relatively coarse and strongly supported by the callosity filling in the space between the hinge-area and the general interior of the valve. In fact, both valves are thick, and represent gerontic conditions. The muscular area is subcircular, with the postero-lateral diductors narrow, bordering the support of the hinge-teeth. The area is crossed by a median ridge, as usual. The interior of the shell is thickened anteriorly, especially along the median parts, and there is a tendency toward a "knotted" elevation of this part of the thickened border as in *Strophomena nutans*. The border is crossed by vascular grooves.

The shell usually does not exceed 23 to 25 mm. in width.

As far as the subpentagonal, nasute outline, and the strong median thickening of the interior of the pedicel valve are concerned, it is believed that these features do not suggest relationship to *Strophomena nutans*, but that they indicate similar gerontic stages of two quite dissimilar species produced by a retarded growth of the shell, accompanied by an increased thickening of the valves, and a more sudden deflection of the anterior and lateral margins. Any marked increase in the amount of shell material added to the interior of the valves is likely to be accompanied by a greater curvature of the valves, to provide the necessary room for the living parts, and if the lateral growth is greatly retarded, the additional room is provided anteriorly, resulting sometimes in a subnasute outline.

In a similar manner, I was not able to convince myself that the specimen from the Clay Cliffs, 3 miles north of Wekwemikongsing, on Manitoulin Island, resembling *Strophomena nutans*, (plate XI, Fig. 8) was not a variation of *Strophomena huronensis*, without any direct connection with the Ohio and Indiana specimens of *Strophomena nutans*.

Strophomena acuta, Winchell and Schuchert[20]

(*Plate VII, Figs. 3 A, B, C, D; Plate IX, Figs. 13 A, B*)

Strophomena acuta was described as a variety of *Strophomena neglecta*, but it is evident from the exterior that it bears no resemblance to that species, nor is it related to *Strophomena incurvata*. *Strophomena incurvata* and *Strophomena neglecta* belong to the group of *Strophomena* characterized by fine radiating surface striae, and by a rounded, flabellate muscular area in the pedicel valve. These features are not possessed by *Strophomena acuta*.

Among the specimens figured in this Bulletin, none are the actual figured types, although they came from the type locality, in the Richmond group, at Spring Valley, Minnesota. The specimens represented by Figs. 3 *A* and *B* on plate VII, belong to the Schuchert collection; those represented by Figs. 3 *C* and *D*, are included in the set numbered 5550 in the collection belonging to the University of Minnesota, and all of them may be regarded as cotypes.

General outline of the shell subtrigonal, the lateral outlines being moderately curved and converging from the cardinal angles toward the rounded anterior margins. Angle between the hinge-line and the general lateral contour of the shell 65 to 70 degrees; less commonly, 82 to 85 degrees. Valves usually wrinkled obliquely along the hinge-line.

Brachial valve flattened for a distance of 8 to 10 mm. from the beak, thence evenly convex toward the anterior margin; slightly, almost imperceptibly concave anterior to the beak for about 2 to 2.5 mm.

Pedicel valve slightly convex near the beak. Greatest concavity about 12 to 13 mm. from the beak.

Of the more prominent striae on the brachial valve about 6 or

[20] *Minnesota Geol. Survey*, vol. iii, p. 388, 1893.

7 occupy a width of 5 mm., separated by 3 or 4, sometimes 5, much less conspicuous striae. The striae of the pedicel valve are equal in number to those of the brachial valve, but the more prominent striae are relatively less conspicuous.

One of the specimens belonging to the Schuchert collection has the following dimensions. Width along the hinge-line, 29.5 mm.; across the center of the shell, 24 mm. Length of the pedicel valve, 21.7 mm.; of the brachial valve, 21 mm. Greatest convexity of the shell equals 8 mm. at 13.5 mm. from the beak; at this point the thickness of the shell is 5 mm. Length of the hinge-area, 29.5 mm.; height, 4 mm. In a more semicircular and more convex specimen from the same locality, belonging to set No. 3550 in the Chicago University collection, the greatest height of the shell is 10 mm. at 11.5 mm. from the beak; the length of the shell is 23 mm.

Leptaena gibbosa, James[21]

(*Plate I, Figs. 5 A, B, C*)

The types of *Leptaena gibbosa*, numbered 1114, are preserved in the James collection, in Walker Musum, at Chicago University. Three of the types are illustrated very inadequately in the present Bulletin. The radiating striae are so fine that they are not indicated with the grating used in the preparation of the accompanying plate. Usually one of the median radiating striations is stronger, sometimes two, and in one specimen, four of these median striations are stronger than any of the remainder. The other striae are very narrow and inconspicuous, about 20 to 26 occurring in a width of 5 mm. The types were found 80 feet above low-water mark in the Ohio River, at Cincinnati, Ohio, in the Economy member of the Eden. Similar specimens were found 11 feet above the base of the Eden at Boyd, on the Kentucky Central division of the Louisville and Nashville Railroad, and north of Ford, Kentucky, about a quarter of a mile before reaching the second railroad tunnel. In *Leptaena invenusta*, from the Gratz shale, 2 miles west of Drennan Springs, Kentucky, the number of radiating striae is about 15 in a width of 5 mm. (*Bull. Denison Univ.*, vol. XIV, plate VII, Fig. 3.)

[21] *Cincinnati Quarterly Journal of Science*, vol. i, p. 333, 1874.

In *Leptaena unicosta,* from the Richmond of Illinois and the states farther northwest, the median striation is much more conspicuous. Sometimes two of the median striae are more prominent. Concentric wrinkles are less conspicuous than in *Leptaena gibbosa,* and the absence of a strong concentrically curved elevation along that part of the pedicel valve where the geniculate deflection takes place, is a noteworthy characteristic.

Leptaena richmondensis, Foerste[22]

(*Plate I, Figs. 6 A, B, C*)

Leptaena richmondensis occurs in the Arnheim (plate I, Fig. 6 *A*) almost throughout the entire area of exposure in Ohio, Indiana, and Kentucky. On the western side of the Nashville dome, it extends southward as far as Clifton, on the Tennessee River. On the eastern side of the Cincinnati geanticline, from Stanford, in Lincoln county, Kentucky, northward into Ohio, and thence westward into Indiana, *Leptaena richmondensis* is confined to the lower part of the upper or Oregonia division of the Arnheim. It is assumed that this is the horizon of *Leptaena* also at the more southern exposures in Indiana, and thence southward as far as Marion and Casey counties, on the western side of the Cincinnati geanticline, in Kentucky. Northwestward, especially in Indiana, *Leptaena* is far less abundant than along the eastern line of outcrop in Ohio and Kentucky, and also southward along the western side of the Cincinnati geanticline, in west-central Kentucky.

Leptaena richmondensis is absent from the Arnheim in the western half of Lincoln county, and from the eastern parts of Boyle and Casey counties, in central Kentucky. It occurs in the northeastern part of Adair county, on Damron Creek, south of Green River, but is absent along the Cumberland River, in the southern part of the state.

In Tennessee, it occurs at the Arnheim horizon, north of Dismukes, 4 miles north of Gallatin. The occurrence at Clifton, on the Tennessee River, in the southern part of the state, has already been mentioned.

At most localities in Ohio, Indiana, and Kentucky, *Leptaena rich-*

[22] *Denison University Bulletin;* vol. xiv, p. 211, 1909.

mondensis makes its appearance in the Arnheim distinctly below the *Dinorthis carleyi* horizon, although locally the two fossils may be found associated. In Ohio, at Madison, in Indiana, and at the more northern localities in Kentucky on the western side of the Cincinnati geanticline, *Leptaena* occurs a short distance above a layer containing *Platystrophia ponderosa.* Farther southward, *Leptaena* and *Platystrophia ponderosa* are associated in the same layers. Still farther southward, *Platystrophia ponderosa* continues a considerable distance above the *Leptaena richmondensis* horizon, these conditions being prevalent throughout central Kentucky as far south as Lincoln, Casey, and Marion counties. For the Arnheim form of *Leptaena,* the term *Leptaena richmondensis-precursor* was proposed. (*Bull. Denison Univ.*, vol. XIV, p. 211. See also the *Ohio Naturalist*, vol. XII, plate XXII, Fig. 7.)

Leptaena richmondensis is not known in the lower or Fort Ancient division of the Waynesville member. In the middle or Clarksville division it makes its first appearance distinctly later than *Strophomena planumbona* and *Strophomena sulcata.* Near Blanchester and Clarksville, in Clinton county, Ohio, and near Fort Ancient, in Warren county, it makes its appearance quite constantly at 7½ feet below the lower *Hebertella insculpta* horizon, and continues from this level at various intervals as far as the base of the Liberty member. It occurs in the upper part of the Clarksville bed also northeast of Somerville, in the southern part of Preble county, and southwest of McGonigle in Butler county.

Leptaena richmondensis is especially abundant at the lower *Hebertella insculpta* horizon, at the base of the upper or Blanchester division of the Waynesville. It occurs at this horizon in southwestern Ohio, from Oxford, in Butler county, to Blanchester, in the southwestern corner of Clinton county, wherever the lower *Hebertella insculpta* zone has been recognized. From this level it occurs at various intervals throughout the upper or Blanchester division. It is especially abundant in the Blanchester division in Ohio, and in the more northern counties in the Ordovician areas of Indiana, as far west as Weisburg, and Moores Hill, in the western part of Dearborn county. From these areas it extends southward in smaller numbers. At Concord, in Lewis county, Kentucky, *Leptaena richmondensis* occurs between 19 and 22 feet below the top of the Blanchester division. At Sunset, in the western part of Fleming county, it is found 12

feet below the top. At Wyoming, in the same county, it is seen 18 feet below the top. At Wyoming and Concord, the occurrences of *Leptaena richmondensis* are distinctly below the *Strophomena neglecta* horizon. It is probable that at these localities *Leptaena* indicates approximately the base of the Blanchester division of the Waynesville. At this horizon, *Leptaena* has not been found, so far, south of Fleming county, in east-central Kentucky.

On the western side of the Cincinnati geanticline, in Indiana, *Leptaena richmondensis* occurs in the upper or Blanchester division of the Waynesville, from the most northern exposures southward to Versailles, in Ripley county; north of Canaan, in the central part of Jefferson county; and at Madison (plate I, Figs. 6 *B*, *C*), in the same county. At the more southern localities in Indiana it is far less abundant than northward. At Milton, in Kentucky, opposite Madison in Indiana, *Leptaena* occurs between 19 and 30 feet below the lowest layers containing *Dinorthis retrorsa*, in strata probably belonging to the upper division of the Waynesville.

Two and a half miles northwest of Brownsboro, in Oldham county, Kentucky, *Leptaena richmondensis* occurs 8 feet below the lowest strata containing *Dinorthis subquadrata*, and also 17 feet lower, below a horizon at which *Calapoecia cribriformis* occurs loose. Three miles west of Brownsboro, in the same county, *Leptaena* is found 10 feet below the *Columnaria calycina* horizon, in strata regarded as belonging to the upper part of the Waynesville member.

Leptaena richmondensis is widespread in the lower part of the Liberty member, especially a short distance above the upper *Hebertella insculpta* horizon. At this horizon, it is found throughout the Ohio areas of exposure as far south as Concord, in Lewis county, Kentucky; and Springdale, in Mason county. At Sunset, in Fleming county, it occurs at the upper *Hebertella insculpta* horizon. At Owingsville, in Bath county, it occurs just below the *Dinorthis subquadrata* horizon. West of Spencer, in Montgomery county, it occurs associated with *Dinorthis subquadrata*, near the base of the Liberty.

In Indiana, *Leptaena richmondensis* occurs in the lower part of the Liberty, especially a short distance above the upper *Hebertella insculpta* horizon, as far south as half a mile south of Olean, in the southeastern part of Ripley county. At Madison,

in Jefferson county, most specimens occur immediately beneath the *Hebertella insculpta* horizon. At the mouth of Bull Creek, in Clark county, *Leptaena* is found associated with *Dinorthis subquadrata*, in the Liberty member.

The distribution of *Leptaena richmondensis* in the upper part of the Liberty and the lower part of the Whitewater has not been determined with care, but the fact that field notes do not contain any mention of *Leptaena* at this horizon suggests that the species probably is rare here, and possibly is even absent.

At the top of the Whitewater bed, *Leptaena richmondensis* is present at Spring Hill, near the home of Harley Wilkinson, in the eastern part of Warren county, Ohio; 1 mile southeast of Fair Haven, in Preble county; along Elkhorn Creek, 3 miles south of Richmond, in Indiana, and at the top of the exposures in the western part of the city of Richmond itself.

The occurrences of *Leptaena richmondensis* on Painter Creek, east of Westport, in Decatur county, and on Honey Creek, in the northwestern corner of Ripley county, in Indiana, are interpreted as of Whitewater age, above the Saluda horizon, but the stratigraphy needs further study.

At Moores Hill, in Dearborn county, *Leptaena richmondensis* occurs from the upper *Hebertella insculpta* horizon at various intervals down to 30, and possibly 40 feet below this level. The exact interpretation of the section, however, needs further study. It may be that the upper or Blanchester division of the Waynesville member thickens westward. At Clarksville, in Clinton county, Ohio, the thickness from the base of the lower *Hebertella insculpta* zone to the base of the upper *Hebertella insculpta* zone is about 28 feet. At Jacksonburg, in Butler county, the interval is 35 feet. Southwest of Brookville, in Franklin county, in Indiana, *Dinorthis carleyi* occurs at the base of the Blanchester division 38 feet below the upper *Hebertella insculpta* horizon. This makes it possible that at Moores Hill the lowest layers containing *Leptaena richmondensis* may belong near the base of the Blanchester division.

Leptaena is common at all of the localities in Franklin and Union counties, in Indiana, at which *Dinorthis carleyi* occurs in the Waynesville member, presumably at the base of the Blanchester division, since the latter unquestionably is the upper horizon at which *Dinorthis carleyi* is found in Ohio, where the presence o

Hebertella insculpta at the *Dinorthis carleyi* horizon fixes the position of the latter.

Leptaena richmondensis occurs in the Waynesville member also at Dismukes, 4 miles north of Gallatin, in Tennessee. The species in the Fernvale member, in the Tennessee River Valley of western Tennessee, in the Mississippi River Valley, and westward, is *Leptaena unicosta*, although *Leptaena rhomboidalis* is listed from the Orchard Creek shales, in Calhoun county, Illinois, and from the Maquoketa of Iowa.

In determining the source of *Leptaena richmondensis*, geographically, it should be noted that it is associated in the Arnheim with *Dinorthis carleyi* and *Rhynchotrema dentata*, and apparently was brought in from the same source as that which furnished these species, arriving a relatively short time before the latter. Again, in the Waynesville member, *Leptaena richmondensis* makes its appearance before *Dinorthis carleyi*, the latter coming in at the lower *Hebertella insculpta* horizon, at the base of the upper or Blanchester division. *Rhynchotrema dentata* is seen farther up in the Blanchester division. *Strophomena concordensis* comes in at the close of the Arnheim, a considerable distance above *Leptaena richmondensis*, *Dinorthis carleyi*, and *Rhynchotrema dentata*. The corresponding species, *Strophomena nutans*, comes in 12 feet above the base of the Blanchester division, a considerable time later than the reintroduction of *Leptaena richmondensis* and *Dinorthis carleyi*, but before the recurrence of *Rhynchotrema dentata*. Since none of these species occur in the Mississippi Valley, they do not appear to have entered Cincinnatian areas from the west. Since *Leptaena richmondensis*, *Dinorthis carleyi*, and *Rhynchotrema dentata* are unknown in the long stretch from Drummond Island to New York State, they do not appear to have come in from the north; *Rhynchotrema neenah*, from Wisconsin and Illinois, is not sufficiently similar to *Rhynchotrema dentata* to indicate the origin of this species from the northwest. Connection with the St. Lawrence Valley and the east appears to be shut off by shaly and sandy Richmond deposits, practically unfossiliferous. This leaves chiefly a southern origin for that part of the Arnheim fauna here under discussion, notwithstanding the fact that the nearest relative to *Dinorthis carleyi* is *Dinorthis retrorsa*, of Wales.

Plectambonites curdsvillensis, sp. nov.

(*Plate X, Figs. 15 A, B*)

In the specimens from the Curdsville bed, at Glenn Creek Station, in the northwestern edge of Woodford county, the interior of the brachial valve is thickened near the anterior and lateral margins, the thickening beginning about 2 or $2\frac{1}{2}$ mm. from the margin and extending to within 1 mm. of the latter. However, between the thickened border and the margin of the valve, the shell is much thinner and is traversed, in the same direction as the radiating striae, by a series of short, vascular grooves, of which about 7 occur in a width of 2 mm. The linear callosity adjoining the hinge-area is narrower than in *Plectambonites rugosa*, and meets the thickened border, described above, rather abruptly. The two median ridges separating the two adductor areas usually are prominent and sharp, as in the less mature stages of *Plectambonites rugosa*, although sometimes thickened anteriorly. The lateral outlines of the adductor areas tend to be crescentic. Six or seven radiating striae occur in a width of 1 mm., with every fourth striation slightly more prominent.

Plectambonites plicatellus, Ulrich[23]

(*Plate I, Figs. 8 A, B*)

The chief characteristics of this species are its small size and coarse radiating striations. The shells attain a width of about 5 mm., and 5 relatively strong and prominent striae occur in a width of 1 mm. The delthyrium is wide, the sides forming an angle of 120 degrees; the lower part is occupied by the chilidium, and the upper part by the cardinal process of the opposite valve. The species is characteristic of the Fulton horizon, at Cincinnati, Ohio.

[23] *Journal, Cincinnati Soc. Nat. Hist.*, vol. i, p. 15, 1879.

Plectambonites rugosa, Meek[24]

(Plate I, Figs. 7 A, B, C; Plate X, Figs. 7 A, B, C, D)

The name *rugosa*, first proposed by James in a list of fossils from the Cincinnati Group, in 1871, was later changed by James to *aspera*, in the belief that the name *rugosa* was preoccupied by *Leptaena rugosa*, a view no longer tenable now that the generic name *Plectambonites* has been adopted for the species typified by *Plectambonites sericea*.

The types of *Plectambonites rugosa* were found about 150 feet above low-water mark of the Ohio River, at Cincinnati, Ohio. This would place them in the Southgate division of the Eden. A series of specimens, labelled as the types of *Leptaena aspera*, in the James collection, preserved in the Walker Museum, at Chicago University, is numbered 1085. None of this series shows the interior surface of either valve. The term *rugosa* was given not on account of the oblique wrinkles along the hinge-line but on account of the roughened surface of the general exterior surface of the valves, especially anteriorly. This roughened surface appears due to the presence of numerous very thin overlapping films of shell material. These films appear to consist of the same extremely fine, silky, fibrous material as that forming the compact body of the valves. Sometimes they are traversed by the same radiating striae as those seen on that part of the exterior surface of the valves where the films are not present. The films may be more or less discrete from one another, but in some specimens they are built up into a solid mass, resulting in a thickening of the valves exteriorly. At the exterior margin of the pedicel valve, this thickening may reach a total of fully 2 mm., and frequently the anterior, more or less vertical slope of this thickening is crossed by lines evidently corresponding to the extensions of the radiating striae. The thickening usually is confined to the anterior half or third of the valves. It may result in a succession of concentric bands, the one nearest the anterior margin being the most conspicuous. At other times, the thickening increases evenly, without any concentric banding, but, most frequently, it is more or less irregular, the films being more or less warped or

[24] *Plectambonites rugosa, Ohio Paleontology,* vol. i, p. 72; plate V, Figs. 3 *f, g, h;* 1873. *Plectambonites aspera,* James, *Cincinnati Quarterly Journal of Science,* p. 151, 1874.

broken into shreds. In most specimens no trace of these films is found, there is no thickening of the valves anteriorly, and the exterior surface is comparatively smooth except where interrupted by the stronger radiating striae. Possibly the films are produced in rapid succession by the mantle, each later film more or less crowding out of its road the earlier films, until the thicker, solid shell material of valves is produced. As a matter of fact, the films should be investigated by means of a series of thin sections, under the microscope, in order to determine their more intimate structure, before theorizing as to their origin. Shells with this structure have a considerable vertical range. They are most abundant in the Eden, ranging from the lowest strata immediately above the Fulton layer into the Southgate layer which furnished the types. Similar specimens occur also in the Waynesville and Liberty members of the Richmond, although the thickening at these upper horizons usually is less prominent. Some of the poorly preserved, silicified specimens from the Curdsville bed appear to have had a similar structure. Possibly this structure is of a more extended range, and may occur sporadically in almost any species of the genus. At any rate, it is not a constant characteristic of any species, as originally supposed by James. At least, in many specimens no trace of it remains.

The oblique wrinkles along the hinge-line, described and rather inadequately figured by Meek, occur not only in the lower and middle Eden but also in the Waynesville beds. They are not constant at any horizon, and do not characterize any species. They are likely to occur in any of the larger specimens, though specimens of medium size also occasionally show the oblique wrinkles.

Under *Leptaena aspera,* James stated that the cardinal line of the brachial valve is straight, and has a crenulated appearance, most conspicuous when held to a strong light. This crenulated appearance is not due to any unevenness of surface, either of the hinge-area or of the exterior surface of the valves. It is seen only when light is transmitted *through* the shell substance, and is most distinct in the more translucent shells. The number of wrinkles varies from 6 to 11 in a width of 3 mm. As viewed ordinarily, the wrinkles appear at right angles with the hinge-line and therefore have no connection with the oblique wrinkles seen on the exterior of the valves. They occur also when viewing the brachial valve by

means of transmitted light, although not as conspicuous as in the case of the pedicel valve. The solution of the problem is seen on examining the interior of the valves. The interior of the brachial valve is slightly thickened along the hinge-line, this thickening being narrowly linear, but increasing slightly in width toward its junction with the thickening bordering the lateral and anterior parts of the valve. In many specimens this interior thickening along the hinge-line is crossed by a series of minute transverse ridges, which, however, do not intrude upon the hinge-area. In the case of the pedicel valve, a similar series of minute transverse ridges is seen upon the linear callosity filling in the space between the hinge-area and the immediately underlying part of the shell. The shell material composing these transverse ridges is deposited by the mantle in an undulating manner, the transverse ridges forming the rising parts of the undulations, and the supposed wrinkles, seen when the shell is viewed by means of transmitted light, correspond to the depressions of the undulations. The phenomenon evidently is one dependent upon the laws of refraction of light, and is connected not with any actual wrinkling of the hinge-area or of the exterior surface, but with the undulating surface of deposition of the shell material along the linear callosities lining the interior of the valves immediately within the hinge-area. From these statements it will be noticed that the supposed wrinkles of *Plectambonites* do not originate along the line of junction of the hinge-area with the posterior line of the exterior surface of the shell, and hence can not have led up to the hollow spines along the posterior margin of *Chonetes*. Specimens showing these supposed wrinkles are more common in the Waynesville bed than in the Eden beds, so that this feature can not be used to distinguish between the two horizons. Moreover, numerous specimens do not show the wrinkling.

Among the specimens referred to *Plectambonites rugosa,* with the oblique wrinkles along the hinge-line, many are 12 mm. long and 25 mm. wide. It is specimens of this large size which occurred 150 feet above the Ohio River at Cincinnati, in the Southgate member of the Eden, and which formed the types of *Plectambonites rugosa*. However, specimens of large size occur also at the base of the Eden.

In the Waynesville member of the Richmond, *Plectambonites* is common in the lower part of the middle or Clarksville division,

from the *Orthoceras fosteri* horizon upward for a distance of 5 to 10 feet. Some of these specimens are very large, frequently reaching a width of 22 mm. These specimens show the oblique wrinkling along the hinge-line, the so-called vertical wrinkles when examined by transmitted light, and the external thickening of the shell due to the presence of more or less discrete or conjoined films, as described in the preceding lines under *Plectambonites rugosa* from the Eden beds. *Plectambonites* occurs also between the lower *Hebertella insculpta* horizon and the strata containing *Strophomena nutans* and *Strophomena neglecta,* in the lower part of the Blanchester division. It is abundant in the lower part of the Liberty member, frequently ranging upward through half of the member. It is seen again in the lower part of the Whitewater member, from 7 to 13 feet above the base, but here it is rather scarce and small.

Various attempts to distinguish the numerous specimens found in the Waynesville and Liberty members from those found in the lower and middle Eden have not proved very successful. As a rule, the delthyrium of the Liberty and Waynesville specimens is narrower, the sides forming an angle of about 67 degrees, while in the Eden specimens this angle usually is about 85 degrees, and the hinge-area is relatively lower. In the former, the three ridges formed by the posterior slopes of the cardinal process and the proximal terminations of the two crural plates, as seen through the delthyrium of the complete shell, diverge less. The median parts of the brachial valve are traversed by two diverging ridges, thickening anteriorly, and sometimes separated anteriorly by two much lower vascular ridges. On each side of the prominent pair of median ridges is an adductor scar. A low ridge, indistinct posteriorly, divides each scar into two parts longitudinally. In the specimens from the Liberty and Waynesville beds, the exterior lateral outline of the adductor areas is approximately crescentic in form, and is fairly well defined posteriorly; anteriorly the exterior half of the adductor scar converges toward the longitudinal ridge separating it from the inner half. In the specimens from the Eden beds, the anterior outline of the adductor scars tends to be more quadratic, the anterior termination of the exterior half of each scar being broader, and more in line with the anterior termination of the inner half of the same scar; posteriorly, the exterior lateral outline of the adductor scars frequently is rather indistinct.

It is doubtful whether it will be possible to make use of these distinctions between the Richmond and the Eden forms of *Plectambonites* except locally. The variations are of the lower rank to which the term *mutations* rather than *varieties*, has been applied recently. The term *Plectambonites rugosa-clarksvillensis* will serve to designate the large specimens from the lower third of the Clarkvsille division of the Waynesville bed, in Ohio and Indiana. With these specimens, those from other horizons in the Clarksville and Blanchester divisions of the Waynesville, and those from the Liberty bed, are regarded as identical.

The difference in outline from transversely elongate quadrangular to semi-elliptical frequently is shown with all intermediate stages on the same slab. All of the shells belonging to the *Plectambonites rugosa* group increase more in width than in length, when attaining a large size. The resultant outline is a matter of luxuriant environment rather than of specific change, and is shown more conspicuously by the larger specimens than by the smaller specimens.

It will be scarcely worth mentioning that these slight differences between forms found at different horizons will be found of interest more by the stratigraphical paleontologist, than by the student of biology. However, if such species as *Plectambonites sericea* are to be of any value for the closer correlation of the smaller divisions of Ordovician formations, the attempt must be made to discriminate between the smaller variations. Whether the present attempt has added anything or not, is another question.

Rafinesquina declivis, James

(Plate VIII, Fig. 10, enlarged)

An enlarged drawing of the same type specimen as that represented by Fig. 12 *C*, on plate V, in vol. XVI of this Bulletin, is here presented, in order to give a better idea of the alternation of single stronger striae with sets of two or three finer striae. The median striation is the most prominent.

Dalmanella emacerata, Hall[25]

(*Plate VIII, Figs. 3 A, B*)

Dalmanella emacerata was described by Hall in the *Thirteenth Report of the Regents of the University of New York, State Cabinet of Natural History*, page 121, in 1860, and first figured in the *Fifteenth Report* of the same series, in 1862, by Figs. 1 to 3, on plate II.

In the original description the shell is stated to be "semi-elliptical, length and width about as five to seven; hinge-line nearly equalling the width of the shell."

Fig. 1, on plate II, of the *Fifteenth Report*, represents a brachial valve 15 mm. in length and 20.5 mm. in width; the ratio of length to width being as three to four. Fig. 2 on the same plate represents a pedicel valve almost 14 mm. in length and 21 mm. in width, the ratio being as two to three.

The type specimens of *Dalmanella emacerata*, numbered 1339–2, are preserved in the American Museum of Natural History in New York City. Both are brachial valves. The one regarded as serving as a basis for Fig. 1 in the *Fifteenth Report*, is 14.5 mm. in length, and 20.8 mm. in width. The dimensions, therefore, agree very well with the ratio of five to seven, and the outline is sufficiently near that presented by Fig. 1 to have served as a basis of this figure.

The chief difference between the specimens typified by Figs. 1 and 2 of the *Fifteenth Report* lies in the more quadrate outline of that typified by Fig. 1, and the more elliptical outline of that represented by Fig. 2. Specimens of the first type are figured in the *Bulletin of Denison University*, vol. XIV, page 213, and plate IV, Fig. 1, as *Dalmanella emacerata-filosa*. They evidently represent typical forms of *Dalmanella emacerata*, and the varietal name *filosa* should be dropped. Specimens of the second type are represented by Fig. 5 on plate VII of the same volume, page 322, as *Dalmanella brevicula*.

In typical *Dalmanella emacerata*, there is a tendency toward the greatest width lying near the line across the middle of the shell. In typical *Dalmanella emacerata-brevicula*, the greatest width of the shell lies distinctly posterior to a line across the middle of

[25] *Thirteenth Regents Report, Univ. of New York*, p. 121, 1860.

the shell. In typical *Dalmanella emacerata* there is a tendency toward a more angular postero-lateral outline. In *Dalmanella emacerata-brevicula* this part of the outline usually is more rounded, but in neither case is this feature sufficiently constant to be of diagnostic value.

In the type of *Dalmanella emacerata,* Hall, as preserved in the American Museum of Natural History, many of the finer striae are more or less obscured by the clay which still adheres to the specimen, but sufficient evidence is presented under a lens to make it certain that the striae of the type are very fine and close, as in the specimen figured under the name *Dalmanella emacerata-filosa.* Near the antero-lateral margins, 16 to 17 striae occur in a width of 5 mm. It is now evident that typical *Dalmanella emacerata* must not be identified with the much more coarsely striated form found in the Fulton bed, 2 feet above the crinoidal top of the so-called Trenton rock as exposed in the First Ward, in Cincinnati, Ohio. These specimens from the Fulton bed, for which the name *Dalmanella fultonensis* (*Bull. Denison Univ.*, vol. XIV, plate VII, Fig. 1) is here proposed, are much more coarsely striate, having only about 10 striae in a width of 5 mm. In coarseness of striae they are more nearly allied to the *Dalmanella multisecta* type of shell.

The horizon of typical *Dalmanella emacerata* is in the Southgate bed, about 160 feet above low-water in the Ohio River, at Cincinnati, Ohio. The lower forms, about 60 feet above the base of the Eden, are somewhat more coarsely striated.

Dalmanella emacerata-brevicula occurs at the same horizons and the value of this varietal designation is still in doubt. The types occur in the Southgate bed. Both forms range up into the lower part of the McMicken bed.

Hebertella subjugata, Hall

(*Plate VIII, Fig. 6*)

In this number of the Bulletin a view of another one of the types of *Hebertella subjugata* is added to that already published on plate II of vol. XVI of this Bulletin. This second type was illustrated by Fig. 1 *N*, on plate 32 *C*, of the *New York Paleontology,* vol. I. It is a less finely striated specimen, and similar specimens are common in the Fairmount and Bellevue

beds at Cincinnati, Ohio. As a matter of fact, they have a considerable vertical range, and form what might be called a museum species, where forms are at times discriminated that can not be kept distinct in the field. *Strophomena subtenta* presents similar difficulties.

Plectorthis fissicosta, Hall

(*Plate VIII, Fig. 4*)

A figure of the pedicel valve of the type specimen, preserved in the American Museum of Natural History, is added to those of the brachial valve of the same specimen published on plate IV, in vol. XIV of this Bulletin. This valve is crushed centrally, but the features are not obscured.

Austinella scovillei, Miller[26]

(*Plate VIII, Figs. 8 A, B, C*)

In the original description of this species, it is stated that the types were collected near Lebanon, Ohio. As a matter of fact, however, they were found about 7 miles northeast of Lebanon, at a locality then known as Freeport, but now called Oregonia. Here they occur 5 feet below the upper *Hebertella insculpta* horizon, in the upper part of the Blanchester division of the Waynesville member of the Richmond. The present location of the types figured by Miller is unknown, but the species is readily identified, and a number of specimens from the James collection, preserved in the Walker Museum, at Chicago University, are here figured. Some of these are labelled as coming from Oregonia, others as having been found at Blanchester, evidently at the same horizon. The exposures at Lebanon belong to the Fort Ancient division of the Waynesville.

Austinella scovillei is regarded as the genotype of the proposed group, *Austinella*. Figs. 8 *B*, and *C*, on plate VIII of this Bulletin, illustrate the narrow, rectangular muscular area of the pedicel valve, characteristic of this group. From the anterolateral angles of this area, branching vascular ridges diverge, only indistinctly indicated in the accompanying figures.

[26] *Journal, Cincinnati Soc. Nat. Hist.*, vol. V, p. 40, 1882.

An interior of a brachial valve is found in the collection of Dr. George M. Austin. Its hinge-area is flat, inclined at an angle of about 20 degrees with the plane passing parallel to the margins of the valve. Cardinal process of medium width, with a narrow groove down the middle posteriorly. A low median elevation extends from the thickened area between the crural plates forward between the areas where the muscle scars should be. Deep and broad dental sockets; no evidence of an extension of the crural plates beyond the anterior margin of the hinge-area.

Austinella kankakensis, from the Richmond at Wilmington, Illinois, is described by McChesney as having 60 to 70 radiating striae. *Austinella whitfieldi,* from the Richmond at Spring Valley, Minnesota, occurs in the same division of the Richmond, and probably is specifically identical with *Austinella kankakensis.* From these species, *Austinella scovillei* differs only in the smaller number of radiating plications.

Austinella whitfieldi, Winchell[27]

(Plate VIII, Fig. 9)

A figure of the quadratic muscular area is presented on plate VIII, Fig. 9. It is more rectangular than in the case of the figures published hitherto, and was secured by photographing a clay cast taken from a sharp natural cast of the interior of a pedicel valve, belonging to the group numbered 8114, in the Gurley collection, preserved in the Walker Museum of Chicago University.

Clitambonites multistriata, sp. nov.

(Plate X, Fig. 12)

Three-quarters of a mile north of the railroad station at Danville, Kentucky, the richly fossiliferous zone belonging to the Faulconer division of the Perryville bed consists of fine-grained whitish limestone. Not all of this section, however, consists of fine-grained limestone. Some of the layers are distinctly granular, but all of the granular layers are distinctly whiter in color than any belonging to the Paris limestone, beneath. In these

[27] *Ninth Ann. Rept. Geol. and Nat. Hist. Survey, Minnesota,* p. 115, 1881. *Minnesota Geol. Survey,* vol. iii, p. 437, 1893.

whitish limestones, a variety of *Clitambonites* with finer and more numerous radiating striae than usual is present. The specimens are broader and much more finely striated than *Clitambonites diversus*, Shaler (plate X, Fig. 13). They probably are more closely related to *Clitambonites americanus*, Whitfield, from the Prosser limestone of Wisconsin and Minnesota, than to the Anticosti species; however, these Danville specimens are more finely striated and broader also than specimens from the Prosser horizon. The distinction is one likely to appeal only to the stratigraphical paleontologist.

Orthorhynchula linneyi, James

(*Plate XI, Fig. 5*)

The Upper Birdseye beds of Linney included both the fine-grained, in part dove-colored limestone overlying the Paris bed, in Mercer and Boyle counties, Kentucky, and also the still higher strata, containing *Stromatocerium, Dinorthis ulrichi, Strophomena vicina, Hebertella frankfortensis* and *Rhynchotrema inaequivalve,* for which the term Cornishville bed was proposed recently. The Perryville member includes that part of the Upper Birdseye limestone of Linney which lies below the Cornishville limestone. Usually it may be divided into two parts. The upper, between 5 and 8 feet thick, is very fine-grained, more or less dove-colored, with small, translucent spots, and with relatively few fossils. The lower part, from 15 to 20 feet in thickness, frequently is darker, and softer, and more fossiliferous. About 1 mile west of Nevada, these lower layers are richly fossiliferous, and are supplied with silicified gasteropods and excellently preserved valves of *Cyrtodonta. Tetradium* is widely distributed at this horizon. Farther eastward, especially between Danville and Harrodsburg, along the railroad, this lower part of the Perryville is even more richly supplied with silicified fossils, and the rock is whiter, and less distinguishable from the so-called dove-colored limestones at the top. Should any separate designation for the lower layers with the silicified fossils be desirable, the term Faulconer limestone will serve. The Perryville limestone thins out northward and northeastward before reaching the Richmond sheet of the United States Geological Survey, from which the Flanagan chert was described. At Flanagan, the Flanagan chert

lies *above* the *Dinorthis ulrichi–Strophomena vicina* horizon, regarded as corresponding to the Cornishville limestone.

Excellent specimens of *Orthorhynchula linneyi* are found in a very fine-grained, white limestone, belonging to the Perryville horizon, about 4 miles north of Versailles, Kentucky. The locality is reached by going from Wallace nearly 1½ miles west and then about the same distance southward, to a turn in the road. The exposures are poor, but loose blocks dragged out from the fields west of the road present beautiful specimens of *Orthorhynchula*, together with *Tetradium* and other fossils usually found in the lower part of the Perryville bed, such as *Isochilina jonesi*. In the specimens of *Orthorhynchula*, the beaks of both valves are less incurved than in the Catheys or Fairmount specimens, so that the delthyrium is better exposed.

Trematospira granulifera, Meek[28]

(Plate VIII, Fig. 5, enlarged)

Pedicel valve with shallow sinus. Median plication narrow, bifurcating, 2 mm. from the beak, into two narrow branches, which at the anterior margin are 0.7 mm. distant from each other. On each side of the resulting median pair of plications there is a distinctly larger plication, forming the sides of the sinus posteriorly, but lying within the depression of the sinus anteriorly. The axes of this second pair of plications are about 3 mm. distant from each other at the anterior margin of the valve. The third pair of plications, counting from the median pair outward, forms the sides of the sinus anteriorly. Their axes are 6 mm. distant from each other anteriorly. Near the beak, all the plications, except the median bifurcating one, are approximately of the same size, but anteriorly they differ considerably. The width of each of the two branches of the median plication is 0.8 mm. The first plication on each side of this median pair is from 1 to 1.2 mm. wide. The second plication on each side, counting from the median pair, varies from 2.2 to 2.4 mm. in width. The third, fourth, and fifth plications on each side also are of considerable width, and, together with the second pair,

[28] *Proc. Acad. Nat. Sci.* Philadelphia, 1872, p. 318. *Ohio Paleontology,* vol. i, p. 128, 1873.

form the prominent, sharp, angular plications of the valve. The sixth plication, near the hinge-line on each side, is inconspicuous. It is impossible to determine from the specimen whether the opening at the beak is due to breakage or not. The beak of the pedicel valve laps over that of the brachial valve, and hides the latter.

Brachial valve with median plication narrow, beginning 2 mm. from the overlapping beak of the pedicel valve, and remaining narrow as far as the anterior margin, where its width is 0.7 mm. The first and second plication, on each side of this median one, are 1 mm. wide, and belong to the median fold, so that this fold bears 5 plications, while the corresponding median sinus of the pedicel valve contains only 4 plications. The ridges of the exterior plications on the fold of the brachial valve are 4 mm. distant from each other, and their exterior sides slope downward into the deep groove separating the second from the third plication. The third, fourth, and fifth pairs of plications are prominent, and are separated by deep wide grooves. The sixth plication on each side, counting from the median one, is considerably less prominent, though considerably more prominent than the sixth plication of the pedicel valve.

Not the slightest trace of a hinge-area is seen on the brachial valve, and practically none in the case of the pedicel valve.

Surface with low, and rather distant, concentric lines of growth. Minute granules, probably connected with a minutely porous structure of the shell. Much larger granules, rather irregularly arranged, but more frequently approximately in line with the concentric lines of growth.

Length, 10 mm.; width, 13 mm.; depth or thickness, 7.2 mm.

The type, numbered 1622, is preserved in the Dyer collection at Harvard University.

The features which suggest the propriety of referring this species to *Trematospira*, in the absence of all knowledge of the interior, are the close enfolding beak of the pedicel valve, obscuring the view of the deltidial plates, and the numerous minute granules, suggesting an abundantly punctate structure for the shell; also the presence of a fairly distinct median fold and sinus. It seems so improbable that any species of *Trematospira* could occur in Cincinnatian strata, that I have suspected for some time that eventually *Trematospira granulifera* would turn out to be an

aberrant specimen of some well known species, for instance, *Trematospira gibbosa*, from the Hamilton of New York. The specimen actually found by the collector at Cincinnati might have been a specimen of *Zygospira cincinnatiensis*, but in the course of time, by a mixture of labels, the *Trematospira* was regarded as Cincinnatian. To be sure, *Trematospira gibbosa* is figured as having only three plications on the fold and two in the sinus, but the type of *Trematospira granulifera* is supposed to be an aberrant specimen. Although intercalated narrow median plications are to be expected in *Rhynchospira* and *Homoeospira* rather than in *Trematospira*, the former genera have no broad median fold and sinus, similar to that of some species included in *Trematospira*.

Lingula procteri-versaillesensis, var. nov.

(*Plate X, Figs. 8 A, B*)

Lingula procteri was described by Ulrich from specimens which passed into the possession of Professor Schuchert, and representative specimens were figured by Hall and Clarke in the *Paleontology of New York*, vol. VIII, part 1, plate I, Figs. 5 and 6. These specimens were obtained at Bank Lick, several miles south of Covington, Kentucky, in strata which stratigraphically belong below the Fulton layer, and therefore below the Eden. In these specimens the concrete laterals of the brachial valve are represented by semi-elliptical areas bordering the median septum, and are traversed by slightly curved, subparallel lines, beginning at the median septum and directed obliquely backward, toward the postero-lateral margins of the muscular areas. Anteriorly, there is a narrow heart-shaped area representing the anterior laterals. In the pedicel valve, the sides of the median septum are rather strongly divergent, and terminate near the center of the valve. The concrete laterals, bordering the median septum, are cuneiform in shape, and, together with the median septum, are bounded anteriorly by a crescentic line from which a number of short lines diverge radially, as in *Lingula vanhorni*.

In the Paris division of the Lexington limestone, within the city limits of Versailles, Kentucky, a species of *Lingula*, which is practically identical with *Lingula procteri* in outline, is common. The exact horizon is 20 feet below the base of the arch of the

concrete bridge crossing the railroad from Versailles to Frankfort, and approximately 20 feet above the *Strophomena vicina* horizon. In the brachial valve of these specimens there is a very narrow and very low median septum. In a specimen 18 mm. in length, this septum is most distinct 11 mm. from the beak. A small obliquely-oval muscular scar is found on each side of the septum. The inner edges of these scars are about half a millimeter distant from the median septum, and lengthwise they extend from 9 to 10.5 mm. from the beak. Their longest diameter is directed toward the antero-lateral outlines of the shell. They represent, apparently, the central scars at the anterior end of the concrete lateral areas, but there is no trace of semi-elliptical concrete laterals, crossed diagonally by subparallel striae, as figured by Hall and Clarke in the case of *Lingula procteri*, although specimens showing the interiors of the brachial valves are not rare. Anteriorly, the median septum can be traced in a much fainter form as far as 13.5 mm. from the beak. This part of the septum separates the rather narrow anterior lateral scars. In the interior of the pedicel valve, there are two very narrow and very shallow grooves, limiting the very low and broad median septum. At a distance of 8 or 9 mm. from the beak, this septum attains a width of about four-fifths of a millimeter, and in some specimens only two-thirds of a millimeter. There is no trace of any other structure. These probably are the specimens to which Ulrich refers in his original description of *Lingula procteri*, when he states that this species ranges from the middle beds of the Trenton in central Kentucky to about 50 feet above low-water mark in the Ohio River at Covington, Kentucky. Considering the fact that most species of *Lingula* have been erected upon variations in the outline of the shell and upon the surface ornamentation, the proposal of a new name based upon interior characteristics can not expect to find welcome; nevertheless, if the discrimination proves an accurate one, it must stand. Science can not profit by the failure to discriminate between *Lingula procteri* and *Lingula versaillesensis*, if the distinctions here pointed out prove to be constant and to belong to different horizons

The shell substance of *Lingula versaillesensis* is very white. The exterior is nearly smooth, and is ornamented by very faint, concentric, broad, flat striations. There is no trace of radiate lines

on the exterior surface, although the interior frequently is marked anteriorly by very fine striae which are slightly divergent and would be called radiate if they extended farther back. The largest specimens attain a length of 19 mm. In these specimens the thickness of the shell equals 4 mm., the valves being equally convex. In width, the specimens vary from 12.5 mm. to 15 and even 16 mm. There is a resultant variation in outline, the former being ovate-oblong, and the latter more broadly ovate in outline. The difference obviously is one of age, the older shells becoming rapidly broader anteriorly but not postero-laterally. For a length of about 7 or 8 mm. the lateral outlines are but slightly convex. Posterior to this part of the outline, the sides converge more rapidly to the rapidly-rounded outline at the beak, and anteriorly, the antero-lateral outline also is rather strongly rounded, compared with the moderate convexity of the anterior margin. The shell is rather evenly convex within the limits of the dimension stated. Even anteriorly the thickness of the shell is fairly well maintained to within 5 or 6 mm. from the anterior margin.

Helicotoma brocki, sp. nov.

(*Plate X, Fig. 11; Plate XI, Fig. 3*)

Helicotoma brocki belongs to the group of species typified by *Helicotoma planulata*, in which a series of revolving striae is found on the lower half of the outer side of the whorls of the shell. These revolving striae, however, are much stronger than in *Helicotoma planulata*, and in consequence, the lower half of the whorl appears more protuberant than in the latter species. There are five revolving striae; of these, two occupy the most prominent part of the lower half of the whorl, with the striation above and that below of equal size and an equal distance apart. The fifth striation is less prominent; it forms the outer edge of the flattened base of the shell, and the distance between it and the striation immediately above is less than between the other striae. The under side of the whorls is strongly flattened or slightly concave, with a rise of the surface at the margin of the umbilicus. Transverse striae very fine, but distinctly seen under a lens. On the lower surface of the whorls they form an angle of about 50 degrees with the outer margin; on the outer sides they form an angle of about 30 degrees with the perpendicular; and on the upper side,

they turn from the marginal notch ridge strongly toward the apertural end for a short distance and then approach the inner edge of the whorls at an angle of about 55 degrees. The umbilical slopes are steep, departing only about 10 degrees from the vertical.

The type specimen was found 35 feet below the margin of the hill south of Kagawong, on Manitoulin Island, associated with *Strophomena sulcata, Strophomena neglecta,* and *Strophomena huronensis,* near the base of the Richmond section. Another specimen was found a short distance southward, at the Kagawong Falls.

Fifteen feet below the base of the Clinton limestone, along Elkhorn Creek, 3 miles southeast of Richmond, Indiana, a specimen of *Helicotoma* was found associated with *Conocardium richmondensis, Beatricea undulata, Columnaria alveolata, Columnaria vacua,* and some species of *Ischyrodonta.* In the immediately overlying part of the section, 3 feet thick, *Ischyrodonta decipiens* is abundant. Eleven feet below the Clinton, *Tetradium* and *Stromatocerium* occur. *Ischyrodonta* is seen again at 7 feet below the Clinton. These strata form the upper part of the Elkhorn member of the Richmond, the base occurring 40 feet below the Clinton, overlying beds containing *Strophomena vetusta*; 15 feet lower, *Strophomena sulcata, Leptaena richmondensis, Dinorthis subquadrata, Rhynchotrema dentata,* and other Whitewater fossils occur.

The species of *Helicotoma* (plate X, Fig. 10; plate XI, Fig. 4), found in the Elkhorn member resembles *Helicotoma brocki* in the steepness of the upper half of the outer side of the whorls; in the marked convexity of the lower half of this side; and in the flatness of the lower side of the whorls, with a moderate concavity lengthwise on this surface. The character of the surface ornamentation of the lower, convex half of the outer surface of the whorls, however, could not be determined from the only specimen collected. All specimens seen were crushed more or less vertically. None were found resembling *Helicotoma marginata,* Ulrich, described from Elkhorn Falls, and evidently from the same locality and horizon as the form here illustrated. The type of *Helicotoma marginata,* numbered 45830, is preserved in the U. S. National Museum, at Washington. The lateral and umbilical sides of the specimen are not exposed. To me, the specimen appeared crushed, as though the second last volution had been pushed up

and over the last volution, thus doing away with the winged idea. Under these circumstances, I should prefer to wait for a specimen showing the remainder of the shell before admitting the presence of a broad, lateral flange.

Orthoceras tyronensis, sp. nov.

(Plate X, Figs. 5 A, B)

In the Tyrone bed at High Bridge, Kentucky, between 24 and 29 feet below the base of the green clay at the top of the formation, the rock is richly fossiliferous. Here the following species of *Orthoceras* is found.

Orthoceracone with circular section, with the apical angle varying from 6 to 10 degrees. On one fragment, 38 mm. in length, the diameter at the larger extremity is 11 mm., and 6.5 mm. at the smaller end. The septa are moderately concave, about 6 occur in a length of 6.5 mm., where the diameter of the shell is 7 mm., the siphuncle at this point is linear in form and about two-thirds of a millimeter in diameter.

The surface of the shell probably is smooth, but in all of the specimens at hand it is covered by a papillose layer, resembling the encrusting growths to which Parks recently has applied the term *Dermatostroma*. This covering sometimes attains a thickness of half a millimeter in specimens 7 mm. in diameter. Many of the papillae are discrete, but frequently they are more or less elongate longitudinally, and coalesce into longer or shorter ridges, which sometimes are strong and bold, considering the small diameter of the shells. For this covering, regarded as an encrusting growth, the term *Dermatostroma tyronensis* is suggested.

Orthoceras tyronensis, with its corticose covering of *Dermatostroma tyronensis* occurs also 7 miles south of High Bridge, nearly 2 miles northwest of Bryantsville, where the road bends northward into a ravine.

Changes in Terminology

For *Schizonema* substitute *Schizoramma*. Type: *Schizoramma fissistriata*. *Bulletin, Denison Univ.*, vol. xiv, p. 76.

For *Bathycoelia* substitute *Pionodema*. Type: *Pionodema subaequata*, Conrad. *Bulletin, Denison Univ.*, vol. xiv, p. 221.

For *Cyclocoelia* substitute *Encuclodema*. Type: *Encuclodema sordida*, Hall. *Bulletin, Denison Univ.*, vol. xiv, p. 227.

PLATE I

Fig. 1. *Strophomena planoconvexa.* *A, C, D,* pedicel valves; *B,* brachial valve. *E,* interior view of pedicel valve. *F,* view of hinge area, copied from *Ohio Paleontology,* vol. I, plate VI, Fig. 2 *C.* Cincinnati, Ohio. Base of Fairmount.

Fig. 2. *Strophomena planoconvexa.* *A,* pedicel valve; *B,* brachial valve. One of a group of similar specimens, occurring in local collections at Wilmington, Ohio, and stated to have been collected in the Waynesville beds at Clarksville. They can not be distinguished in any manner from *Strophomena planoconvexa,* and apparently are typical basal Fairmount specimens from the vicinity of Cincinnati.

Fig. 3. *Strophomena sinuata.* *A,* pedicel valve; *B, C,* brachial valves. Cincinnati, Ohio, from the middle part of the Fairmount.

Fig. 4. *Strophomena sulcata.* *A, B,* brachial valves, differing in the coarseness of the radiating striae; *C,* interior of pedicel valve. *A* is much more sulcate along the anterior edge than is indicated by the figure. Dutch Creek, 4½ miles northwest of Wilmington, Ohio. Near top of Whitewater member.

Fig. 5. *Leptaena gibbosa.* *A, B,* pedicel valves; radiating striae too fine to be indicated by the figure. *C,* interior view of brachial valve. Cincinnati, Ohio. Economy member of Eden. Type specimen, number 1114, James collection, Walker Museum at Chicago University.

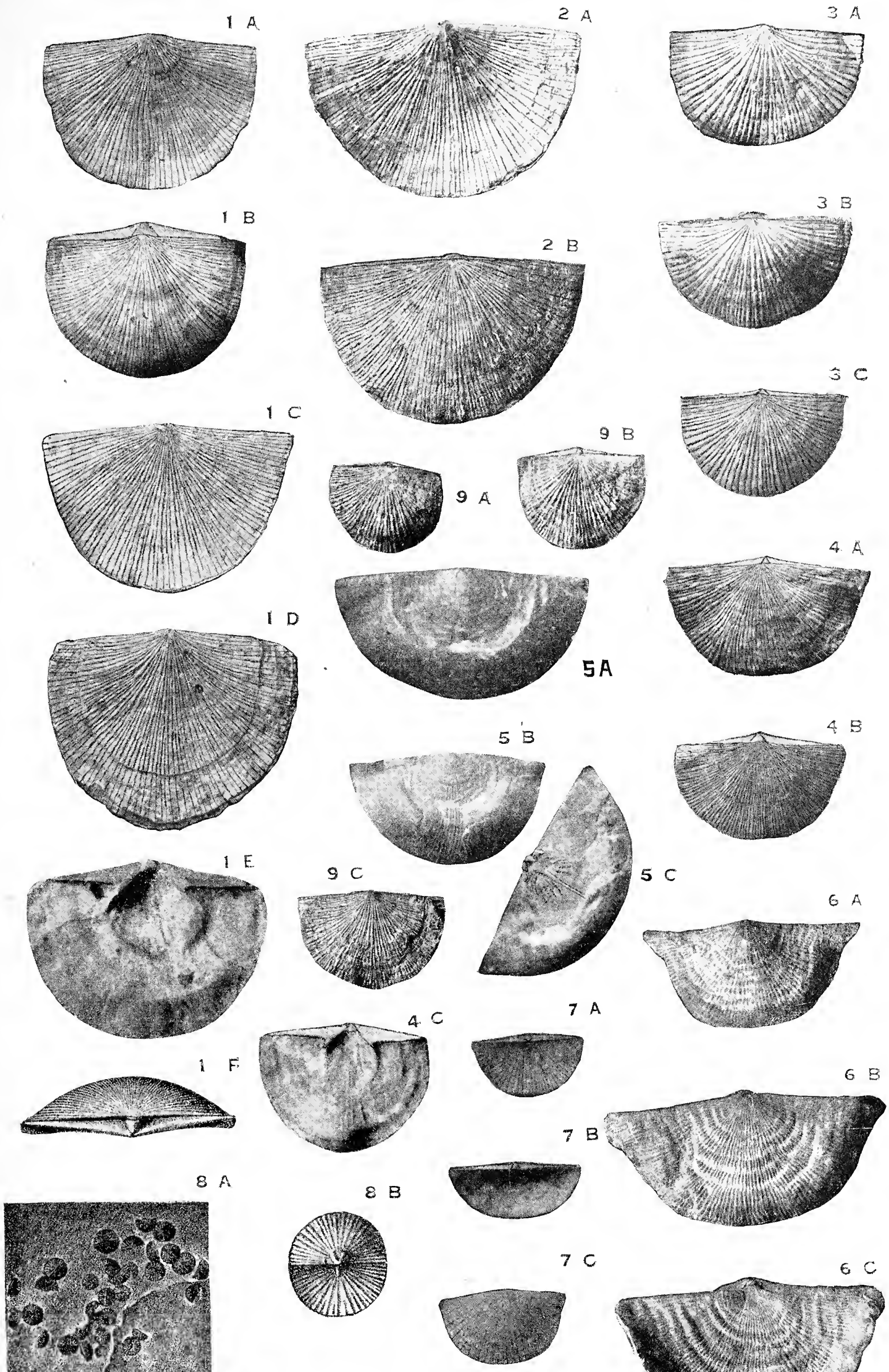
Fig. 6 *A.* *Leptaena richmondensis-precursor.* Pedicel valve. Arnheim, Ohio. Arnheim member.

Fig. 6. *B, C.* *Leptaena richmondensis.* *B,* pedicel valve; *C,* brachial valve. Madison, Indiana. Waynesville member.

Fig. 7. *Plectambonites rugosa-clarksvillensis.* All specimens nine-tenths of natural size. *A, B,* brachial valves; *C,* pedicel valve. Concord, Kentucky, from lower part of Liberty member.

Fig. 8. *Plectambonites plicatellus.* *A,* a group of shells, some of them open but with the valves still attached. *B,* enlarged 5 diameters, with the brachial valve at top of figure. Copied from *New York Paleontology,* vol. VIII, part 1, plate XV *A,* Figs. 34, 35.

Fig. 9. *Strophomena millionensis.* *A, B,* brachial valves; *C,* pedicel valve. An eighth of a mile west of the tunnel west of Million, Kentucky. Near the base of the Eden exposures in that part of Kentucky.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3 A
1 B
2 B
3 B
3 C
1 C
9 B
9 A
4 A
1 D
5A
5 B
4 B
1 E
9 C
5 C
6 A
7 A
4 C
1 F
6 B
7 B
8 A
8 B
7 C
6 C

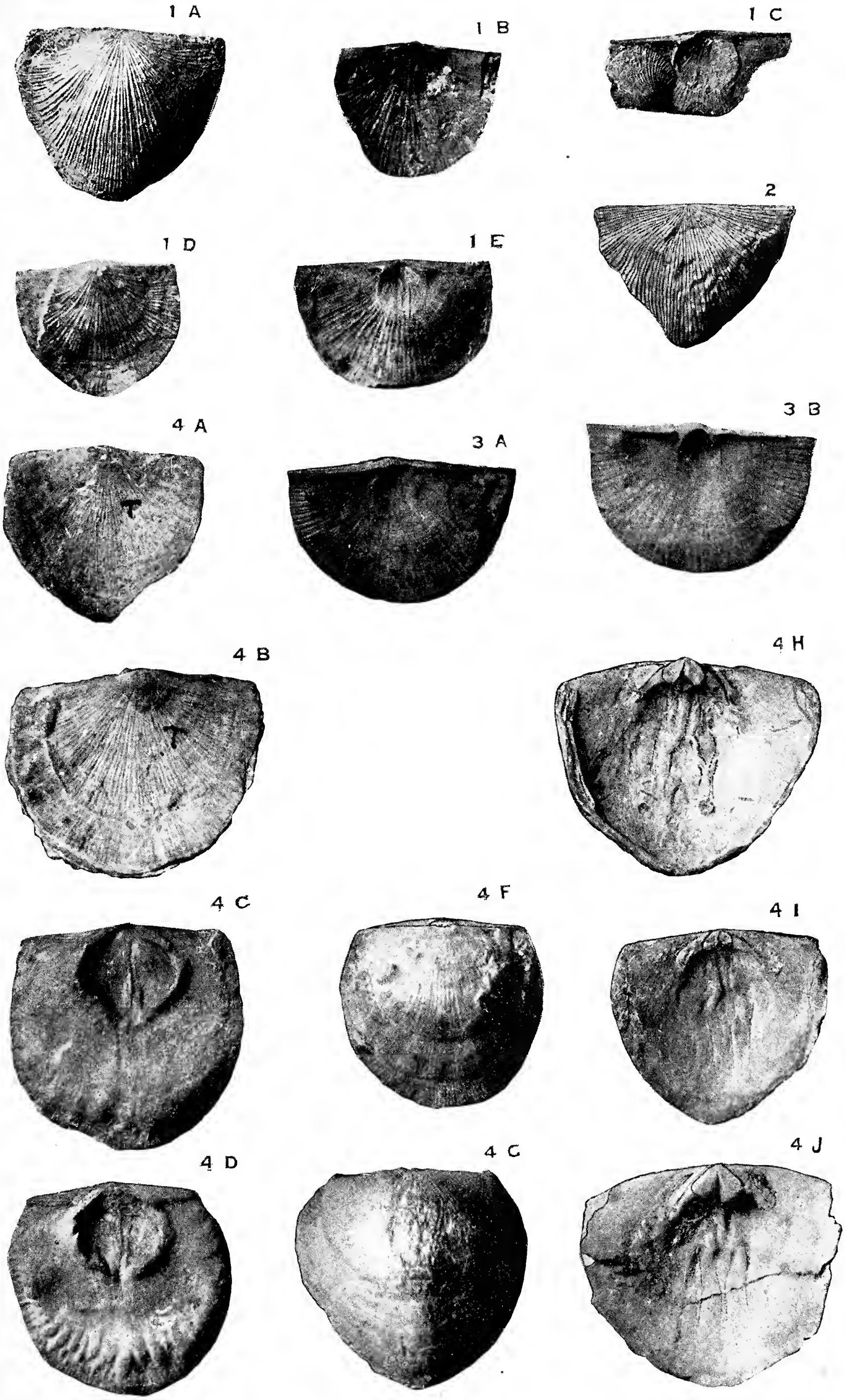
PLATE II

Fig. 1. *Strophomena hallie.* *A,* brachial valve; *B,* interior of brachial valve; *C,* interior of fragment of pedicel valve; types, number 8848, Faber collection, in Walker Museum at Chicago University; Columbia Avenue, Cincinnati, Ohio, Southgate member of the Eden. *D,* pedicel valve; Limestone Creek, southeast of Maysville, Kentucky, in Southgate member. *E,* interior view of pedicel valve; in railroad cut, east of home of George Million, over a mile southeast of Million, Kentucky, at the top of the Southgate member, immediately below the Paint Lick member of the Eden.

Fig. 2. *Strophomena hallie,* variety. Apparently only an aberrant, triangular form presented by a single individual. Brachial valve. Near base of Eden as exposed west of tunnel, 1 mile west of Million, Kentucky.

Fig. 3. *Strophomena higginsportensis.* *A, B,* pedicel valves, interior views. See also plate X, Fig. 4, for another view of 3 *B.* Stony Point, east of Higginsport, on Kentucky side of Ohio River. Apparently near base of Eden, but exact horizon unknown.

Fig. 4. *Strophomena maysvillensis.* *A, B,* pedicel valves; *C, D,* interiors of pedicel valves; *F, G,* brachial valves; *H, I, J,* interiors of brachial valves. Maysville, Kentucky. Lower part of Fairmount.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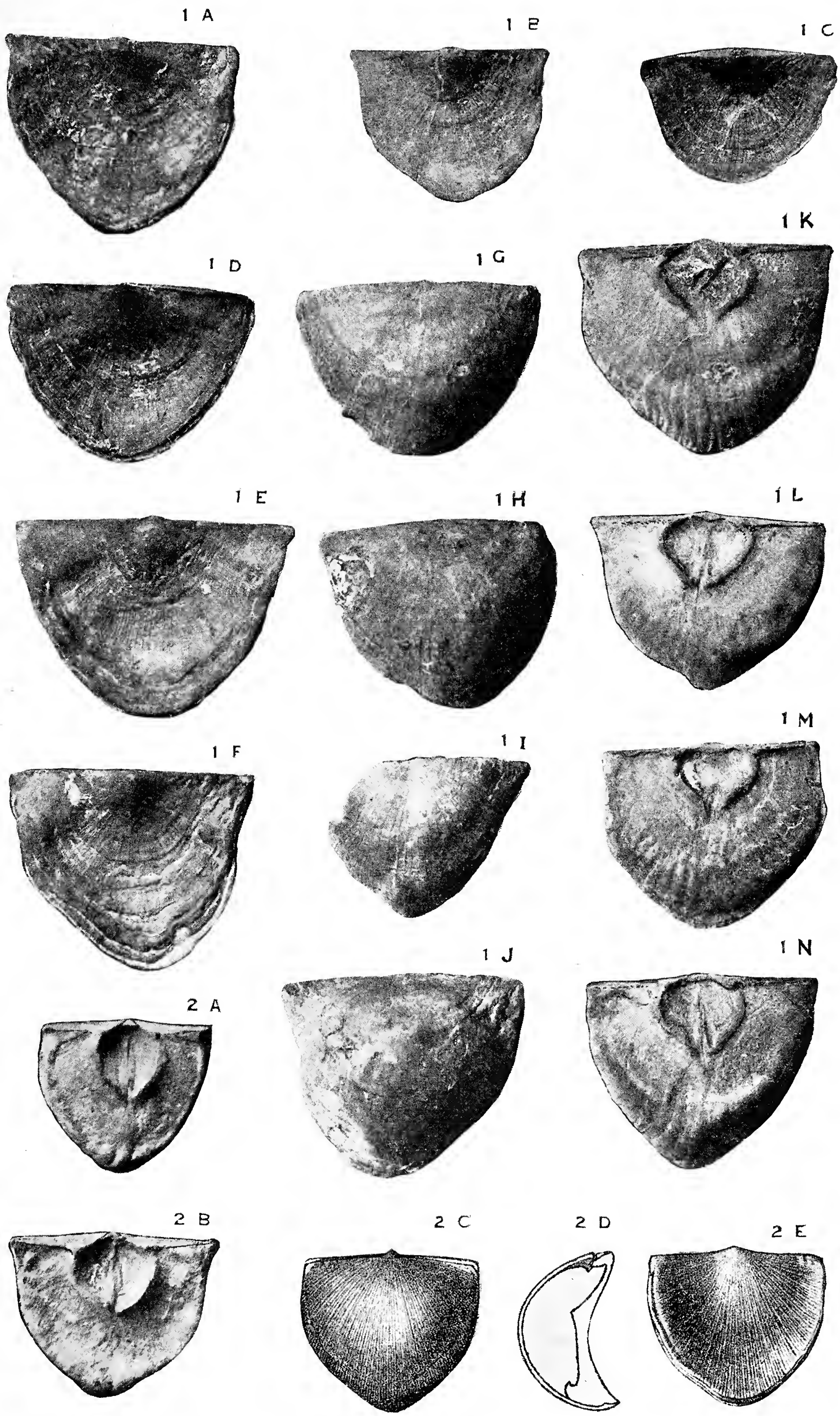
1 B
1 C
2
1 D
1 E
4 A
3 A
3 B
4 B
4 H
4 C
4 F
4 I
4 D
4 G
4 J

PLATE III

Fig. 1. *Strophomena concordensis*. *A*, *B*, *C*, *D*, *E*, *F*, pedicel valves; *G*, *H*, *I*, *J*, brachial valves; *K*, *L*, *M*, *N*, interiors of pedicel valves. Concord, Kentucky, from extreme top of Arnheim.

Fig. 2. *Strophomena nutans*. *A*, interior view of pedicel valve; Oregonia, Ohio. *C*, brachial valve; *D*, profile section with brachial valve on left and pedicel valve on right; *E*, pedicel valve; copied from *Ohio Paleontology*, vol. I, plate VI, Figs. 1 *A*, *F*, *B*; types of the species, now lost; exact locality unknown. All of these specimens came from the Blanchester division of the Waynesville.

Fig. 2 *B*. *Strophomena* resembling *Strophomena nutans*. Pedicel valve, interior view. Richmond, Indiana, at the *Rhynchotrema dentata* horizon in the Whitewater member of the Richmond group.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1 D
1 G
1 K
1 E
1 H
1 L
1 F
1 I
1 M
1 J
1 N
2 A
2 B
2 C
2 D
2 E

PLATE IV

Fig. 1. *Strophomena elongata.* *A, B,* pedicel valves; *C, D, H, L,* interior views of pedicel valves; *I,* brachial valve; *E, F, G, J, K,* interior views of brachial valves. See also plate IX, Figs. 4 *A, B,* for other views of 1 *I.* Figs. 1 *A, B, I,* illustrate very well the outline of the typical specimens as seen in series number 510, James collection, Walker Museum, Chicago University, although not selected from this series of types. Fig. 1 *H,* is one of the cotypes of the James collection. *A, E, F, G, J, K,* are from the Waynesville member, at Madison, Indiana. *C, D, L,* belong to the Nickles collection. *C,* Waynesville member at Oregonia. *D,* Waynesville member at Madison, Indiana. *L,* Liberty member, at Richmond, Indiana.

Fig. 2. *Strophomena planumbona-gerontica.* *A,* pedicel valve; *B,* hinge-area; *C,* brachial valve. Madison, Indiana. Waynesville member. See also plate XI, Fig. 6.

Fig. 3. *Strophomena planumbona.* *A,* pedicel valve; *B,* interior of pedicel valve. Madison, Indiana. Waynesville member.

Fig. 4. *Strophomena planumbona-subtenta.* *A,* pedicel valve; *B, C,* brachial valves; *D,* interior of pedicel valve. Concord, Kentucky. Liberty member.

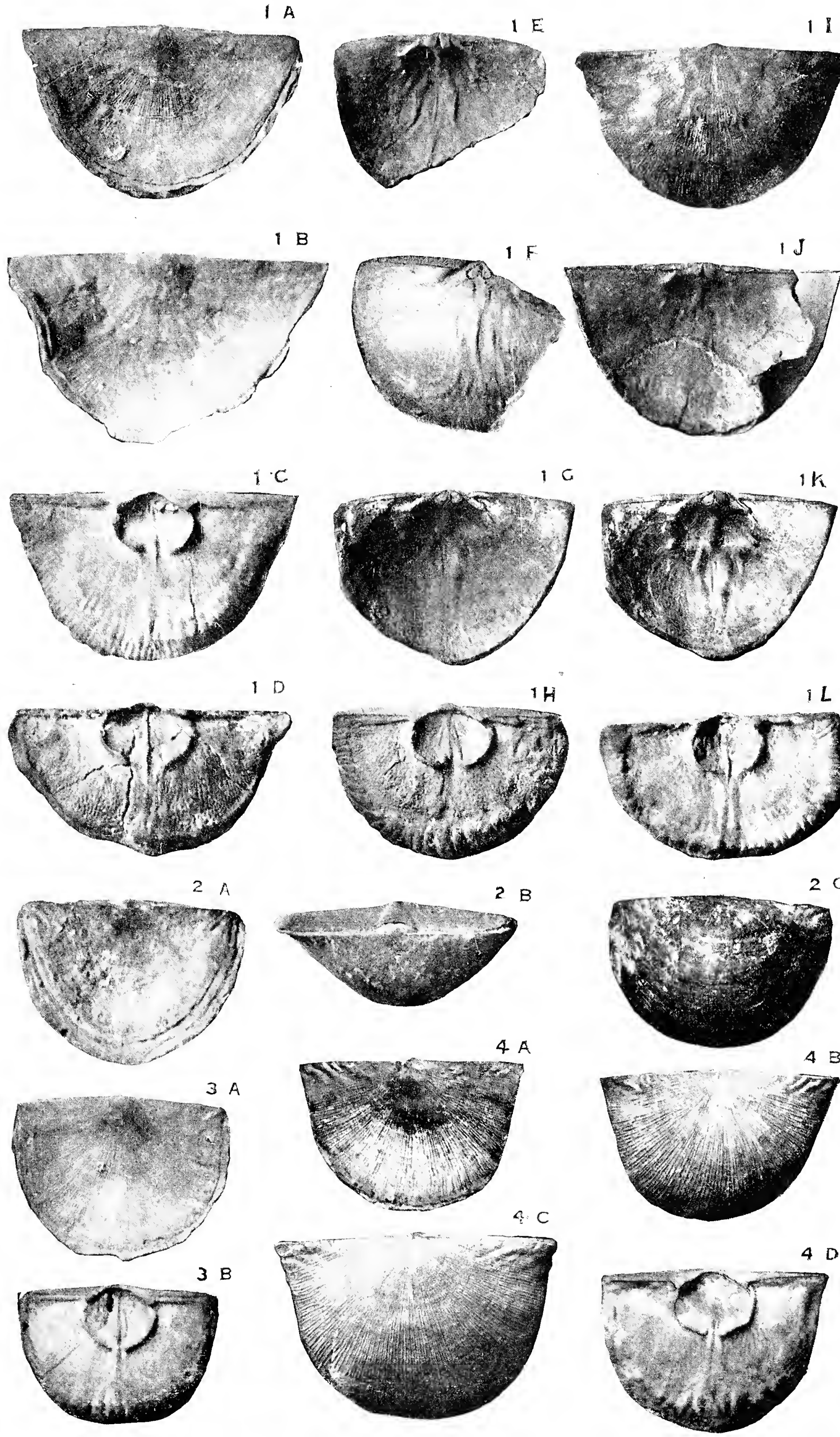

1 A
1 E
1 I
1 B
1 F
1 J
1 C
1 G
1 K
1 D
1 H
1 L
2 A
2 B
2 C
4 A
4 B
3 A
4 C
3 B
4 D

PLATE V

Fig. 1. *Strophomena neglecta*. *A*, brachial valve; *B*, pedicel valve; both from the type specimen, number 2393, in the James collection, Walker Museum at Chicago University. Specimen imperfect, missing outline supplied in wax; original outline probably nearer Fig. 3 *F*, as shown by right side of this specimen. See also plate IX, Figs. 1 *A*, *B*, *C*. Near Blanchester, Ohio. Blanchester division of the Waynesville.

Fig. 2. *Strophomena neglecta*? This is the second specimen included under number 2393, in the James collection, but probably is nearer *Strophomena vetusta-precursor* than *Strophomena neglecta*. It is evident from Meek's description, that specimens of this type were not included among the types he received from James. *A*, brachial valve; *B*, pedicel valve. Near Blanchester, Ohio. Blanchester division of the Waynesville.

Fig. 3. *Strophomena neglecta*. *A*, *B*, *C*, pedicel valves, interior views; *D*, pedicel valve, with subquadrate outline; *E*, interior view of brachial valve; *F*, exterior of brachial valve. *A*, *B*, from Oregonia; *B*, from the Nickles collection. *C*, *D*, *F*, from Clarksville, Ohio. *E*, from Moores Hill, Indiana. All from the Blanchester division of the Waynesville member.

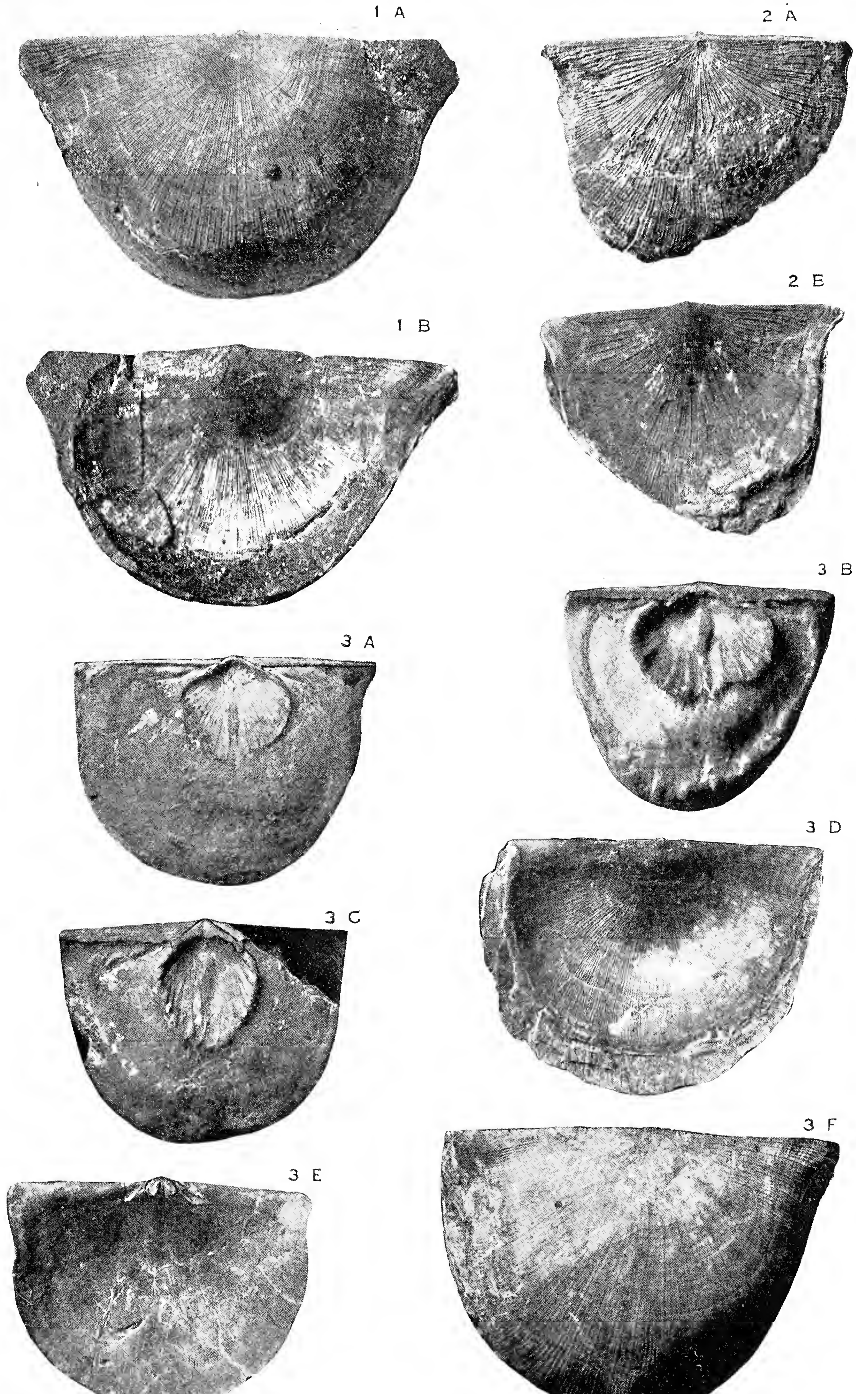

1 A
2 A
2 E
1 B
3 B
3 A
3 D
3 C
3 F
3 E

PLATE VI

Fig. 1. *Strophomena approximata.* *A*, brachial valve; *B*, pedicel valve; type specimen, number 2394, James collection, in Walker Museum, at Chicago University. *C*, brachial valve; *D*, pedicel valve, specimen in same series, but not a type. Definite horizon not known, but either Liberty or Whitewater. Dearborn county, Indiana.

Fig. 2. *Strophomena vetusta.* *A*, *C*, brachial valves; *B*, *D*, *H*, *G*, pedicel valves; *E*, interior of brachial valve; *F*, interior of pedicel valve. *B*, *C*, *D*, *E*, types, number 1567, James collection, in Walker Museum at Chicago University; labelled as coming from Blanchester, Ohio. Either from Liberty or Whitewater members. *A*, Clinton county, Ohio; *F*, Dayton, Ohio; both from Whitewater member. *G*, *H*, Cane Springs, Kentucky, from southern extension of Liberty member.

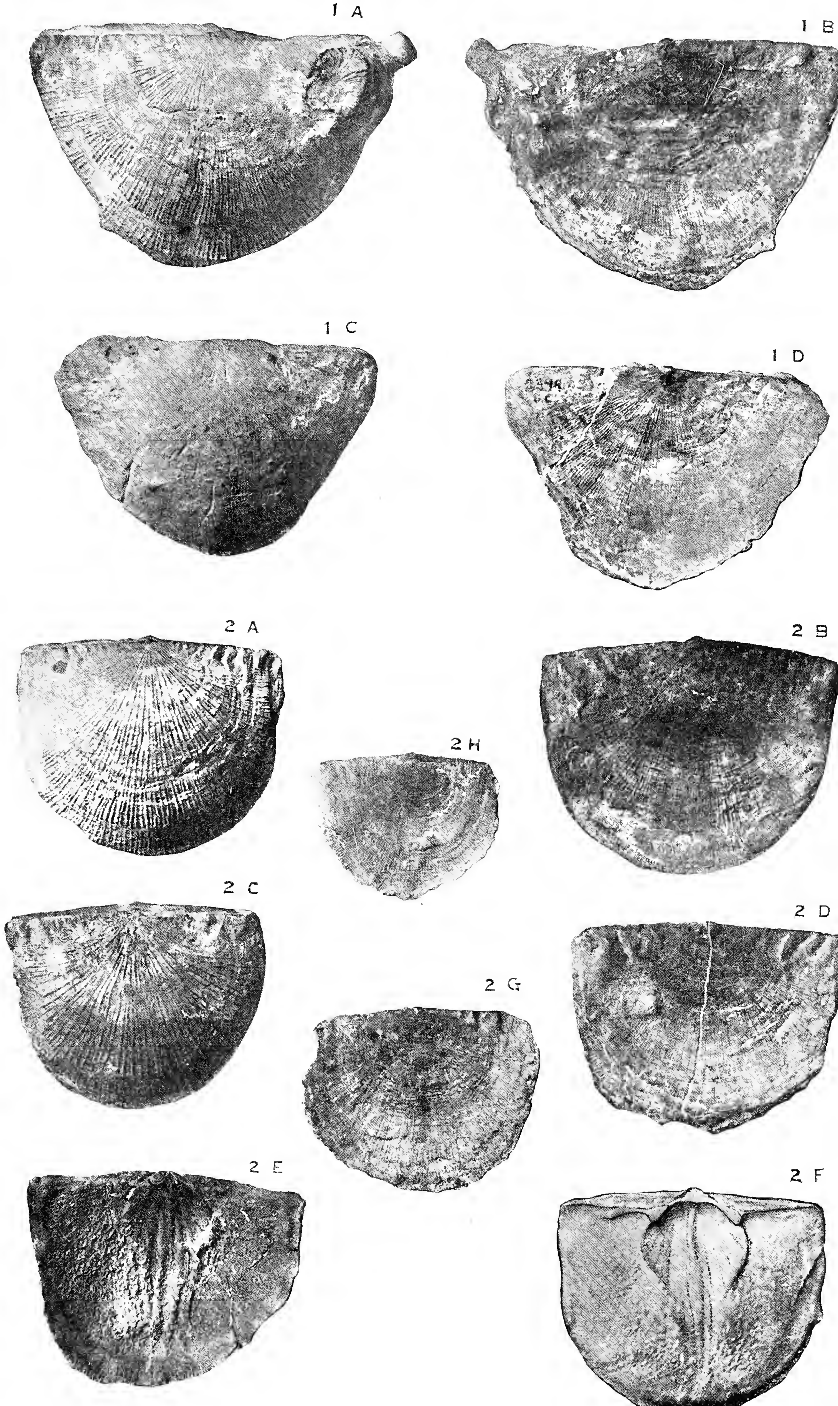

1 A
1 B
1 C
1 D
2 A
2 B
2 H
2 C
2 D
2 G
2 E
2 F

PLATE VII

Fig. 1. *Strophomena wisconsinensis*. *A*, pedicel valve; *B*, brachial valve; *C*, interior of pedicel valve. Wilmington, Illinois. Richmond group. Schuchert collection. See also plate IX, Figs. 5 *A*, *B*, *C*.

Fig. 2. *Strophomena vicina*. Pedicel valve, magnified 1.5 times. Northeast of Becknerville, Kentucky. Paris member. See also this Bulletin, vol. XIV, plate VII, Fig. 12 *A*.

Fig. 3. *Strophomena acuta*. *A*, brachial valve. See also plate IX, Figs. 13 *A*, *B*. *B*, pedicel valve; *C*, pedicel valve; *D*, brachial valve. *A*, *B*, from Schuchert collection. *C*, *D*, from University of Minnesota collection. Spring Valley, Minnesota. Richmond group.

Fig. 4. *Strophomena planodorsata*. *A*, pedicel valve; *B*, brachial valve. Mannie clay, forming upper part of Richmond group, a quarter of a mile northeast of Fly, beyond the home of R. S. Elam. See also plate IX, Figs. 14 *A*, *B*.

Fig. 5. *Strophomena neglecta*. Interior of pedicel valve. Richmond group. Savannah, Illinois. Schuchert collection. See also plate X, Fig. 10.

Fig. 6. *Strophomena planodorsata*. Interior of pedicel valve. Richmond group. Wilmington, Illinois. Schuchert collection. See also plate IX, Fig. 7.

Fig. 7. *Strophomena planodorsata*. *A*, interior of pedicel valve; *B*, brachial valve. See also plate IX, Figs. 8 *A*, *B* for other views of 7 *B*; and Fig. 9 for other view of 7 *A*.

Fig. 8. *Strophomena planodorsata*. Interior of pedicel valve, enlarged 2.5 times. Richmond group. Iron Ridge, Wisconsin. University of Minnesota collection.

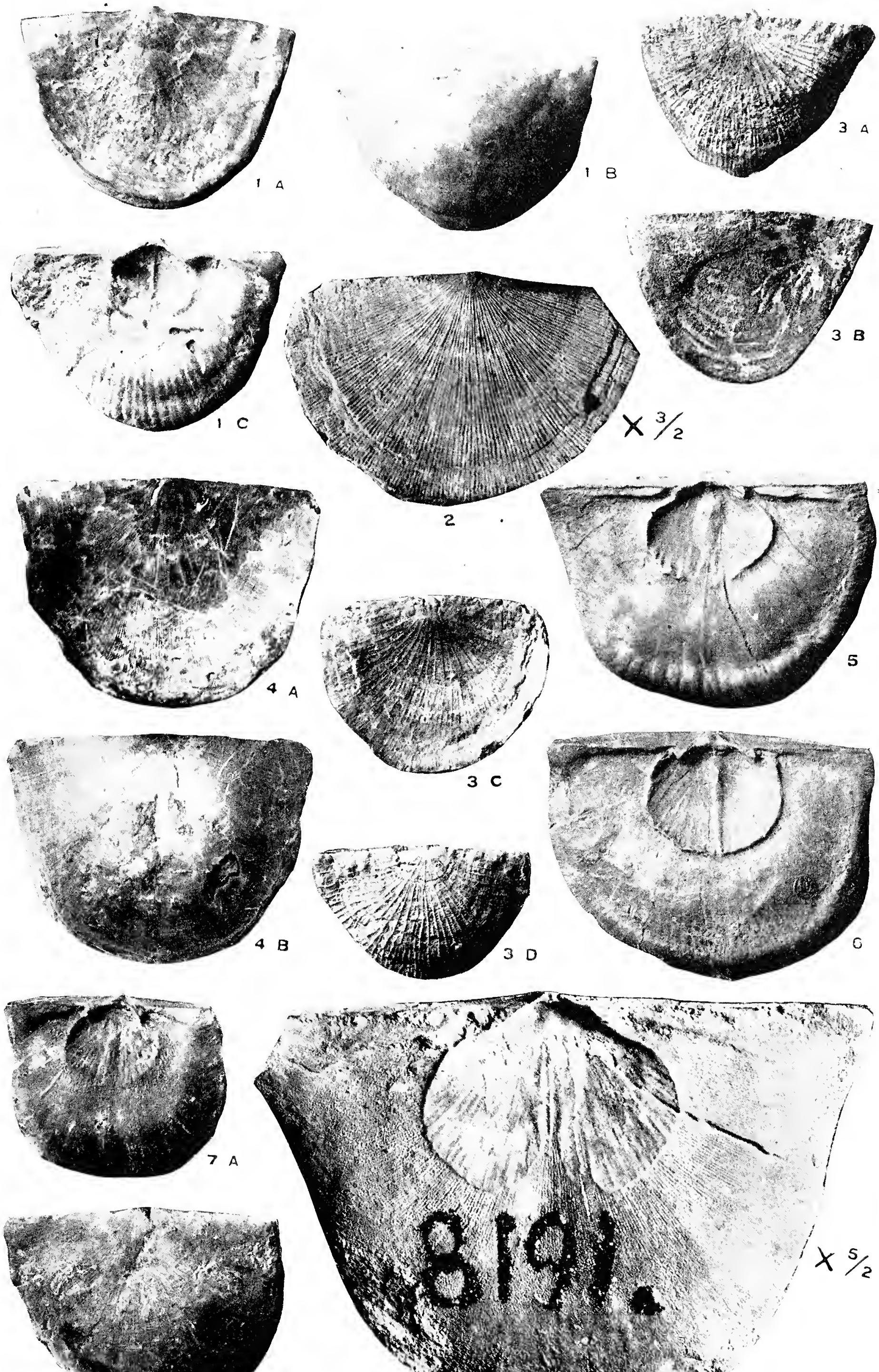

1 A
1 B
3 A
1 C
3 B
X 3/2
2
4 A
5
3 C
4 B
3 D
6
7 A
8191.
X 5/2
7 B
8

PLATE VIII

Fig. 1. *Strophomena planumbona.* *A*, *B*, pedicel valve, one view enlarged. *C*, *D*, brachial valves, one view enlarged. *E*, interior of pedicel valve. See also plate IX, Figs. 3 *A*, *B*. Type specimens, number 918–3, in the American Museum of Natural History, in New York City. Probably from Waynesville member, at Oxford, Ohio. Originals of Figs. 4 *a*, *b*, *c*, on plate 31 *B*, *Paleontology of New York*, vol. 1.

Fig. 2. *Strophomena subtenta.* *A*, *B*, brachial valves, one of the views enlarged. Type specimen, number 922–2, in the American Museum of Natural History, in New York City. Waynesville member of the Richmond; Oxford, Ohio. See also plate IX, Fig. 2.

Fig. 3. *Dalmanella emacerata.* *A*, *B*, brachial valve, one of the views enlarged. Type specimen, number 1339–2, in the American Museum of Natural History, in New York City. Original of Fig. 1; plate II, *Fifteenth Report of the New York State Museum.* Probably from Southgate member of Eden, at Cincinnati, Ohio.

Fig. 4. *Plectorthis fissicosta.* Pedicel valve, somewhat crushed. Type specimen, number 4490, in the American Museum of Natural History, in New York City. See also this Bulletin, vol. XIV, plate IV, Figs. 5 *A*, *B*, for views of the brachial valve. Fairmount member, at Cincinnati, Ohio.

Fig. 5. *Trematospira granulifera.* Brachial valve. Type specimen, number 1622, in Dyer collection, Harvard University. There is no hinge-area, the line in the figure having been added to suggest the amount of curvature of the beak of the pedicel valve. Said to have been found at Cincinnati, Ohio, but the origin is entirely unknown. Probably a Silurian or Devonian shell.

Fig. 6. *Hebertella subjugata.* Brachial valve. Type specimen, number 1342–1. Original of Fig. 1 *n*, on plate 32 *C*, *New York Paleontology*, vol. I. Cincinnati, Ohio. Probably near Bellevue horizon.

Fig. 7. *Acidaspis, species?* Cephalon, rather imperfect. Number 9581, in the Faber collection, belonging to the Walker Museum, Chicago University. Lowry, Ohio. Horizon unknown. See also plate X, Fig. 6.

Fig. 8. *Austinella scovillei.* *A*, pedicel valve; number 105, James collection. *B*,*C*, interiors of pedicel valves; numbers 107, 106, James collection, Walker Museum, Chicago University. *A*, from Blanchester, Ohio. *B*, *C*, from Oregonia, Ohio, the type locality. Blanchester division of the Waynesville.

Fig. 9. *Austinella whitfieldi.* Interior of pedicel valve. Number 8114, in Gurley collection, in Walker Museum, Chicago University. Spring Valley, Minnesota. Richmond group.

Fig. 10. *Rafinesquina declivis.* Pedicel valve, enlarged almost twice the original diameter. See also this Bulletin, vol. XVI, plate V, Fig. 12 *C*. Boyd's Station, Kentucky. Type specimen, from series number 2392, in the James collection, in Walker Museum of Chicago University.

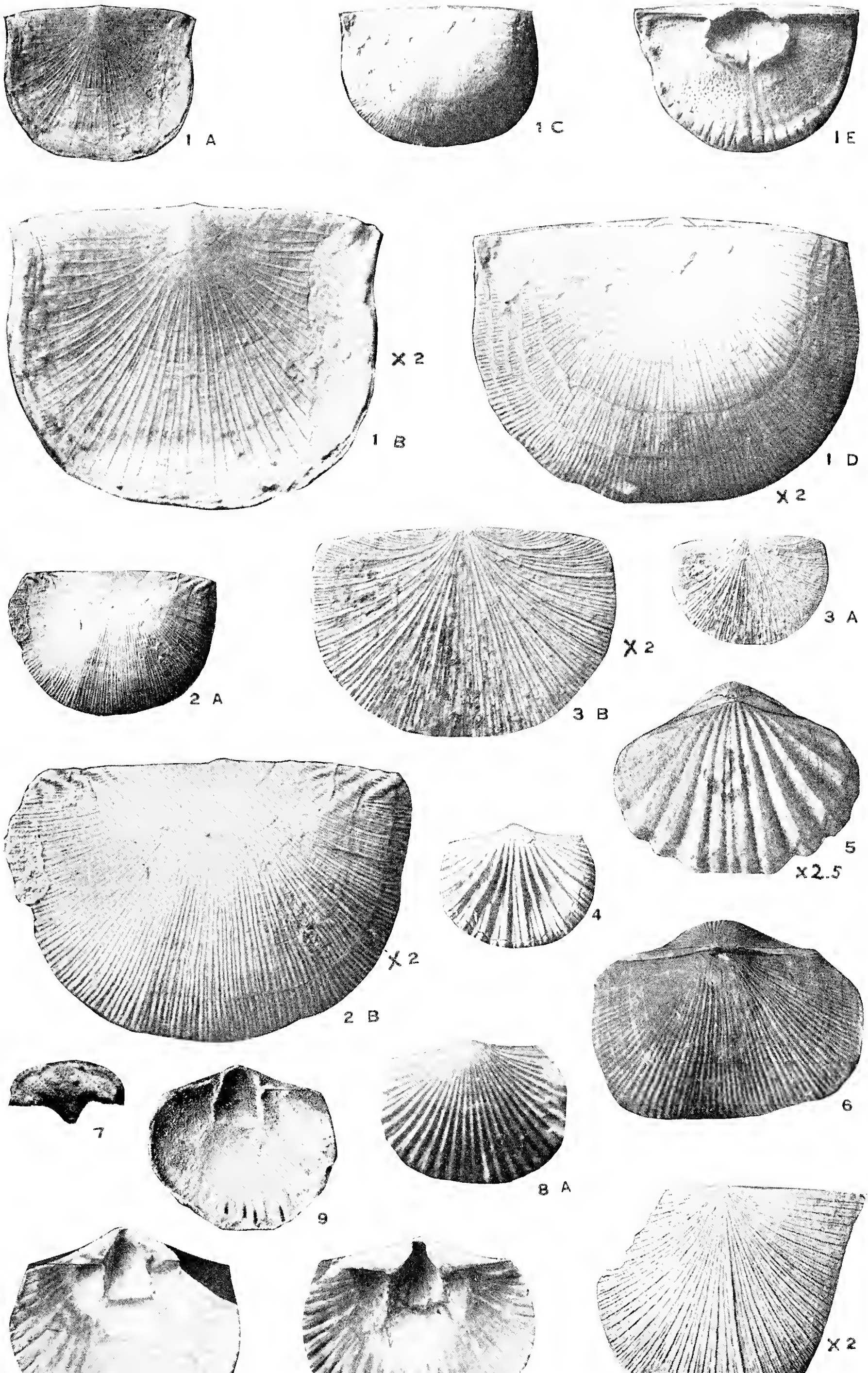

1 A
1 C
1 E
X 2
1 B
1 D
X 2
3 A
2 A
X 2
3 B
5
x 2.5
4
X 2
2 B
6
7
9
8 A
X 2
8 B
8 C
1 0

PLATE IX

Fig. 1. *Strophomena neglecta.* *A*, view along hinge area; *B*, brachial valve, with outlines restored; *C*, lateral view, with indication also of the curvature of the pedicel valve. Type specimen, number 2393, in the James collection, belonging to Walker Museum of Chicago University. See also plate V, Figs. 1 *A*, *B*. One mile west of Blanchester, Ohio. Blanchester division of the Waynesville.

Fig. 2. *Strophomena subtenta.* Curvature of brachial valve, viewed from the side. See also plate VIII, Figs. 2 *A*, *B*. Type specimen, number 922–2, in the American Museum of Natural History, in New York City; Oxford, Ohio. Waynesville member of the Richmond.

Fig. 3. *Strophomena planumbona.* *A*, view along the hinge area; *B*, lateral view, with indication also of the curvature of the pedicel valve. See also plate VIII, Figs. 1 *A*, *B*, *C*, *D*, *E*. Type specimen, number 918–3, in the American Museum of Natural History, in New York City, labelled as coming from Cincinnati, Ohio, but probably from Oxford, Ohio, in the Waynesville member.

Fig. 4. *Strophomena elongata.* *A*, view along the hinge area; *B*, lateral view, with indication also of the curvature of the pedicel valve. Type specimen, number 510, in the James collection, belonging to Walker Museum of Chicago University. See also plate IV, Fig. 1 *I*. Waynesville member. Possibly from Clarksville, Ohio.

Fig. 5. *Strophomena wisconsinensis.* *A*, view along hinge area; *B*, *C*, lateral views, with indications also of curvature of pedicel valves. *B* is a lateral view of *A*. See also plate VII, Figs. 1 *A*, *B*. Schuchert collection. Wilmington, Illinois. Richmond group.

Fig. 6. *Strophomena planodorsata.* *A*, lateral view, with indication also of curvature of pedicel valve; *B*, brachial valve. Type specimen, University of Minnesota collection. Richmond beds, Spring Valley, Minnesota. Copied from *Minnesota Paleontology*, vol. III, part 1, 1893. Plate XXXI, Figs. 8, 9.

Fig. 7. *Strophomena planodorsata.* Lateral view, showing curvature of pedicel valve. Type specimen, Schuchert collection. See also Plate VII, Fig. 6; and *Minnesota Geology*, vol. III, part 1, 1893, plate XXXI, Fig. 10. Wilmington, Illinois. Richmond group.

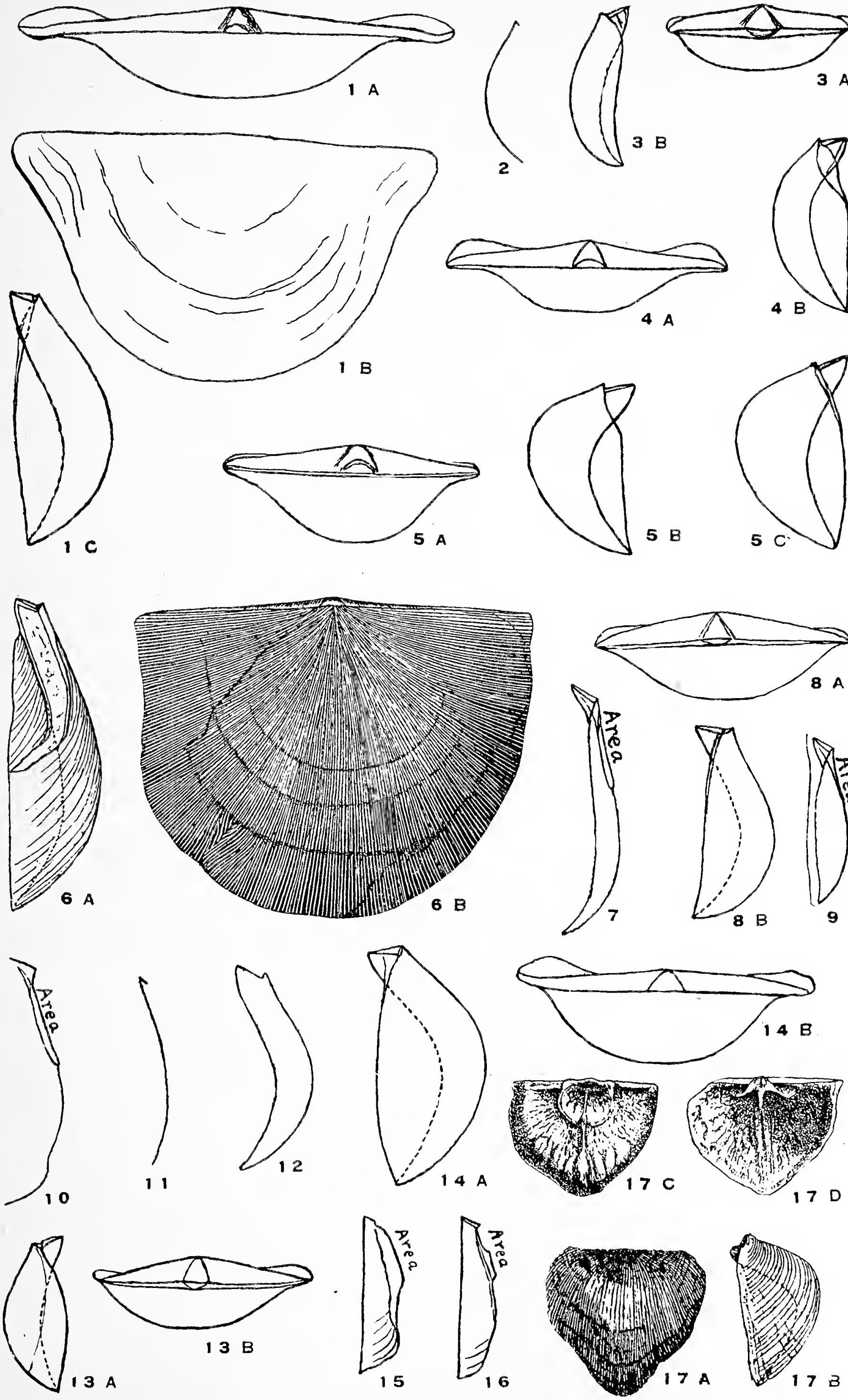
Fig. 8. *Strophomena planodorsata.* *A*, view along the hinge-area; *B*, lateral view, with indication of the curvature of the pedicel valve. Specimen much bent by crushing. Schuchert collection. Wilmington, Illinois. Richmond group. See also plate VII, Fig. 7 *B*.

Fig. 9. *Strophomena planodorsata.* Curvature of pedicel valve, seen from the side. Schuchert collection. Wilmington, Illinois. Richmond group. See also plate VII, Fig. 7 *A*.

Fig. 10. *Strophomena neglecta.* Curvature of interior of pedicel valve, seen from the side. Cited, but not figured by Schuchert in *Minnesota Geological Survey*, vol. III, 1893, p. 388. Savannah, Illinois. Schuchert collection. Richmond group. See also plate VII, Fig. 5.

Fig. 11. *Strophomena planodorsata.* Curvature of pedicel valve, seen from the side. Specimen, number 8191, University of Minnesota collection. Iron Ridge, Wisconsin. Richmond group. See also plate VII, Fig. 8.

Fig. 12. *Strophomena planodorsata.* Curvature of valves, antero-posteriorly. Nickles collection. Sterling, Illinois. Richmond group.


1 A
1 B
1 C
2
3 A
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4 A
4 B
5 A
5 B
5 C
6 A
6 B
7
Area
8 A
8 B
9
Area
10
Area
11
12
13 A
13 B
14 A
14 B
15
Area
16
Area
17 A
17 B
17 C
17 D

PLATE IX—Continued

Fig. 13. *Strophomena acuta.* *A*, lateral view, with indication of curvature of pedicel valve. Schuchert collection. Spring Valley, Minnesota. Richmond group. See also plate VII, Fig. 3 *A*.

Fig. 14. *Strophomena planodorsata.* *A*, lateral view, with indication of the curvature of the pedicel valve; *B*, view along hinge area. Mannie clay, forming upper part of Richmond group, a quarter of a mile northeast of Fly, beyond the home of R. S. Elam. See also plate VII, Figs. 4 *A*, *B*.

Fig. 15. *Strophomena nutans.* Lateral view of pedicel valve, showing contour of interior. Blanchester division of Waynesville. Oregonia, Ohio. See also plate X, Fig. 2 *A*.

Fig. 16. *Strophomena nutans.* Lateral view of pedicel valve, showing contour of interior. Clarksville, Ohio. Blanchester division of the Waynesville. See also plate X, Fig. 3 *B*. The convexity of the interior outline of the valve is slightly exaggerated.

Fig. 17. *Strophomena fluctuosa-occidentalis.* *A*, brachial valve; *B*, lateral view, with indication of curvature of pedicel valve; *C*, interior of pedicel valve; *D*, interior of brachial valve. Richmond group, at Spring Valley, Minnesota. Copied from *Minnesota Geology*, vol. III, plate XXXI, Figs. 14, 15, 16, 17.

PLATE X

Fig. 1. *Strophomena vetusta-precursor.* *A*, Brachial valve. *B*, Pedicel valve. *C*, Interior of pedicel valve. Two miles southwest of Clarksville, Ohio, on Penquite Run, south of the pike to Middleboro. Blanchester division of the Waynesville.

Fig. 2. *Strophomena nutans.* Three interiors of pedicel valves. *A*, from Oregonia, Ohio; see also plate IX, Fig. 15. *B*, *C*, from the same locality. Blanchester division of the Waynesville.

Fig. 3. *Strophomena nutans.* Not the typical form, but approaching *Strophomena concordensis* in general appearance. *A*, *B*, *C*, *D*, interiors of the pedicel valve. Stony Hollow, northwest of Clarksville, Ohio. Blanchester division of the Waynesville.

Fig. 4. *Strophomena higginsportensis.* Interior of pedicel valve. Same specimen as Plate II, Fig. 3 *B*. Stony Point, east of Higginsport, Kentucky. Horizon unknown, but probably low in the Eden.

Fig. 5. *Orthoceras tyronensis* covered by *Dermatostroma tyronensis.* *A*, High Bridge, Kentucky; *B*, nearly 2 miles northwest of Bryantsville, Kentucky, where the road turns northward and descends into a ravine. Tyrone member.

Fig. 6. *Acidaspis, species?* Cephalon, imperfectly preserved; magnified 1.8 diameters. Same specimen as that on Plate VIII, Fig. 7. Number 9581, Faber collection, in Walker Museum, Chicago University. Lowry, Ohio. Exact horizon unknown.

Fig. 7. *Plectambonites rugosa-clarksvillensis.* *A*, *B*, *C*, three interiors of brachial valves; *D*, interior of pedicel valve. *A*, southeast of Oxford, Ohio; *B*, Concord, Kentucky; *C*, exact locality unknown; *D*, east of Weisburg, Indiana. *A*, Clarksville division of the Waynesville; *C*, probably the same horizon; *B*, *D*, lower part of Liberty member.

Fig. 8. *Lingula procteri-versaillesensis.* Brachial valves. *A*, older individual. *B*, younger form. Versailles, Kentucky, along the railroad to Frankfort. Upper part of Paris bed.

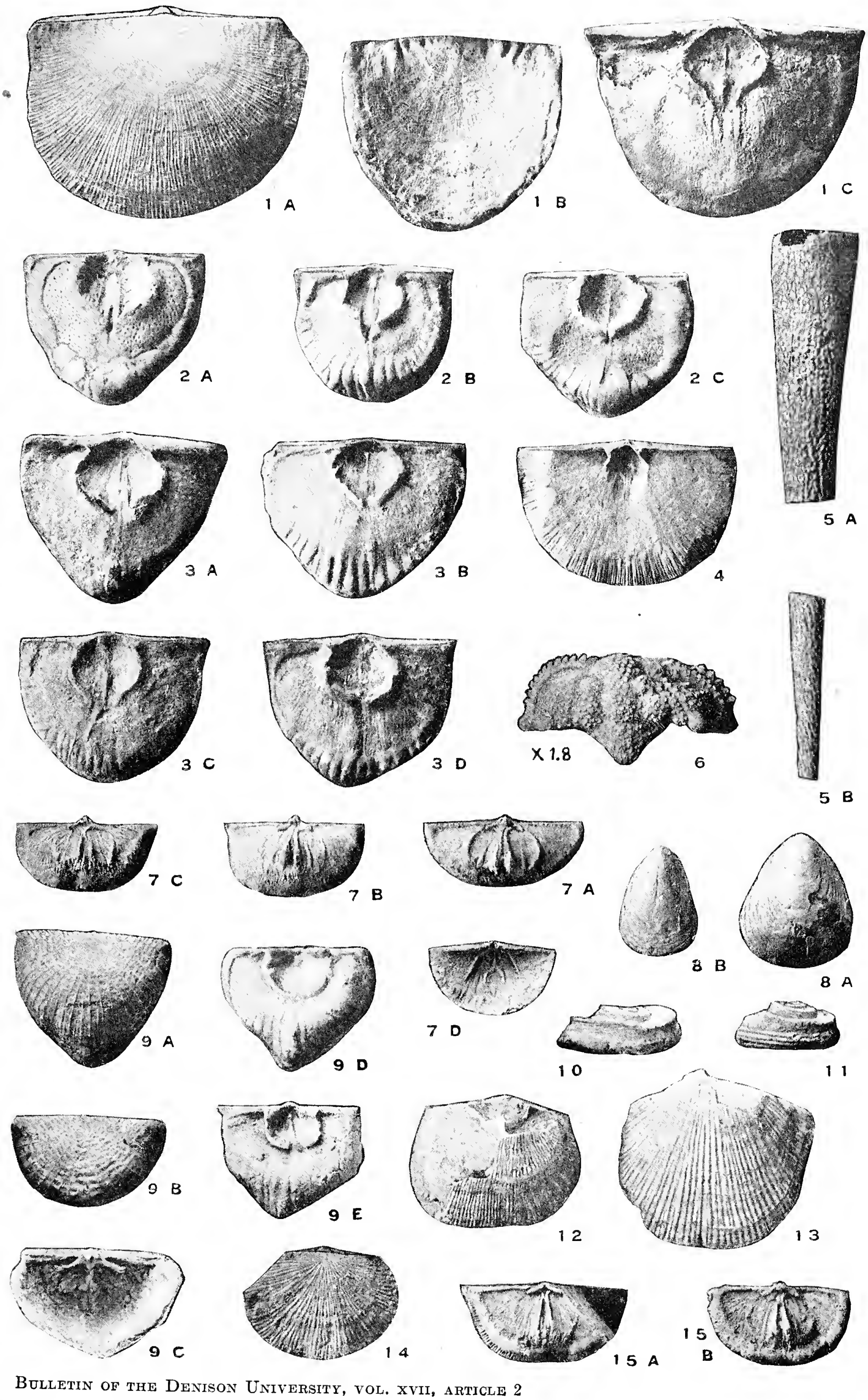

1 A
1 B
1 C
2 A
2 B
2 C
5 A
3 A
3 B
4
3 C
3 D
X 1.8
6
5 B
7 C
7 B
7 A
8 B
8 A
9 A
9 D
7 D
10
11
9 B
9 E
12
13
9 C
14
15 A
15 B

PLATE X—Continued

Fig. 9. *Strophomena fluctuosa-occidentalis.* *A, B,* brachial valves, with the concentric wrinkles not well brought out by photography. *C,* interior of brachial valve, the valve strongly tilted so as to show the muscular area. *D, E,* interiors of the pedicel valve. F. W. Sardeson collection. Spring Valley, Minnesota. Richmond formation.

Fig. 10. *Helicotoma* sp. Lateral view of the specimen figured on Plate XI, Fig. 4. West of Elkhorn Falls, 3 miles southeast of Richmond, Indiana. Elkhorn member.

Fig. 11. *Helicotoma brocki.* Lateral view of the specimen figured on Plate XI, Fig. 3. Kagawong, Manitoulin Island. Richmond formation.

Fig. 12. *Clitambonites multistriata.* Partially exfoliated pedicel valve. Half a mile north of the railroad station at Danville, Kentucky. Perryville bed.

Fig. 13. *Clitambonites diversus.* Pedicel valve. Ellis Bay. Anticosti.

Fig. 14. *Strophomena millionensis.* Brachial valve. An eighth of a mile west of the tunnel west of Million, Kentucky. Lower part of Eden.

Fig. 15. *Plectambonites curdsvillensis.* Brachial valves, interior views. Southwest of Crow Distillery, Glenn Creek, Woodford county, Kentucky. Curdsville bed.

PLATE XI

Fig. 1. *Strophomena concordensis-huronensis.* *A, B, C, D, E,* interiors of pedicel valves; *F, G,* pedicel valves with wrinkles along the hinge line; *H, J,* brachial valves with wrinkles along the hinge-line; *K,* interior of brachial valve. Clay Cliffs, 3 miles north of Wekwemikongsing, east end of Manitoulin Island. Richmond group.

Fig. 2. *Strophomena sulcata.* *A,* brachial valve. *B,* pedicel valve. Kagawong, Manitoulin Island. Richmond group.

Fig. 3. *Helicotoma brocki.* Kagawong, Manitoulin Island. Richmond group. See also Plate X, Fig. 11.

Fig. 4. *Helicotoma* sp. West of Elkhorn Falls, 3 miles southeast of Richmond, Indiana. Elkhorn member of the Richmond. See also Plate X, Fig. 10.

Fig. 5. *Orthorhynchula linneyi.* Brachial valve, with beak of pedicel valve showing above it. Four miles north of Versailles, Kentucky. Perryville bed.

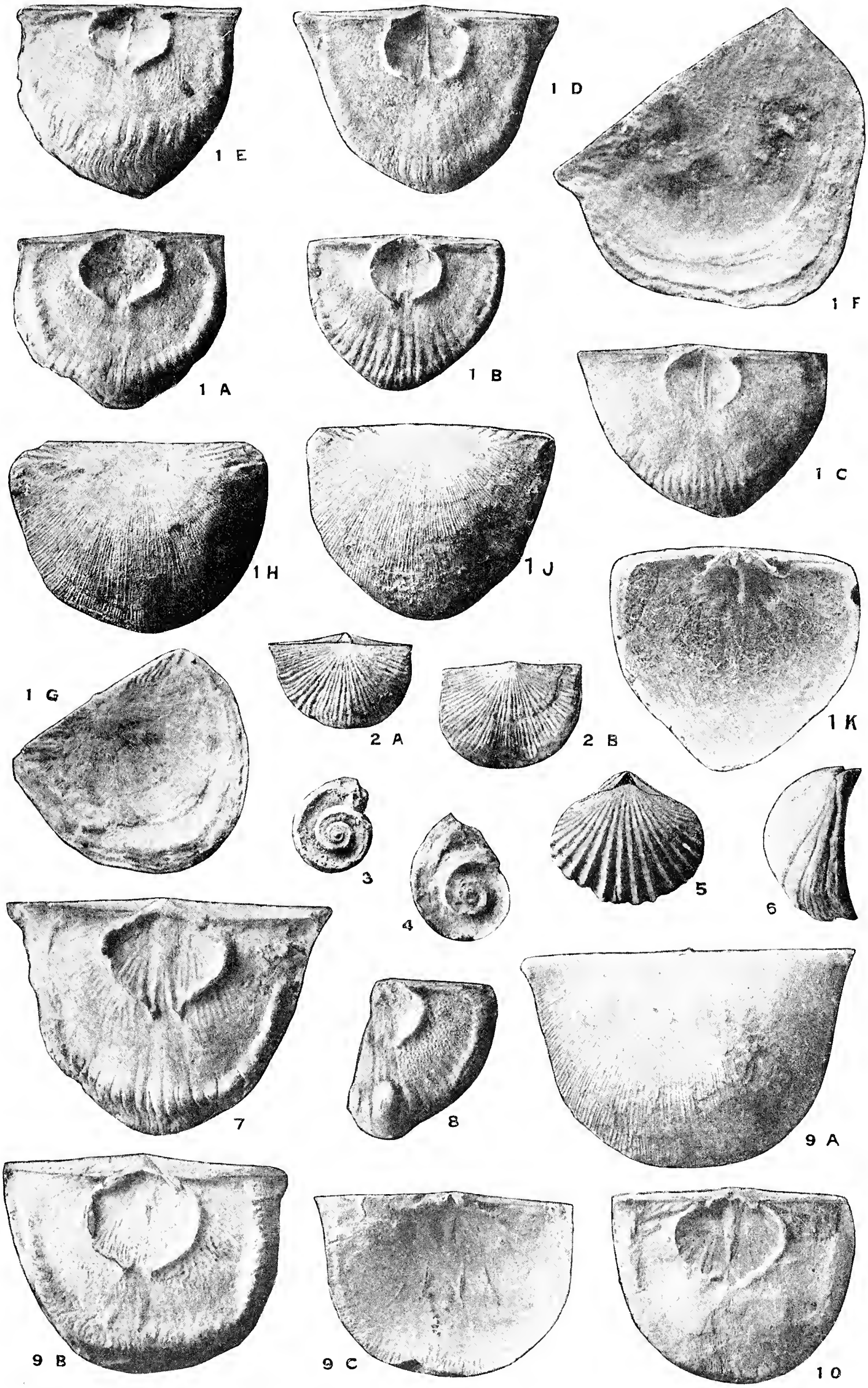
Fig. 6. *Strophomena planumbona-gerontica.* Lateral view, showing convexity and obesity of brachial valve. Hillside west of Gore Bay, Manitoulin Island. Richmond group.

Fig. 7. *Strophomena incurvata.* Pedicel valve, interior view. High Bridge, Kentucky. Tyrone member of High Bridge limestone.

Fig. 8. *Strophomena nutans.* Fragment of pedicel valve, interior view. Clay Cliffs, 3 miles north of Wekwemikongsing, Manitoulin Island. Richmond formation.

Fig. 9. *Strophomena incurvata.* *A,* brachial valve; *B,* pedicel valve, interior view; *C,* brachial valve, interior view. *A,* LaCloche Island; *B, C,* Goat Island; both northeast of Manitoulin Island. Black River formation.

Fig. 10. *Strophomena neglecta.* Pedicel valve, interior view. Kagawong, Manitoulin Island. Richmond group.


1 E
1 D
1 F
1 A
1 B
1 C
1 H
1 J
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1 G
2 A
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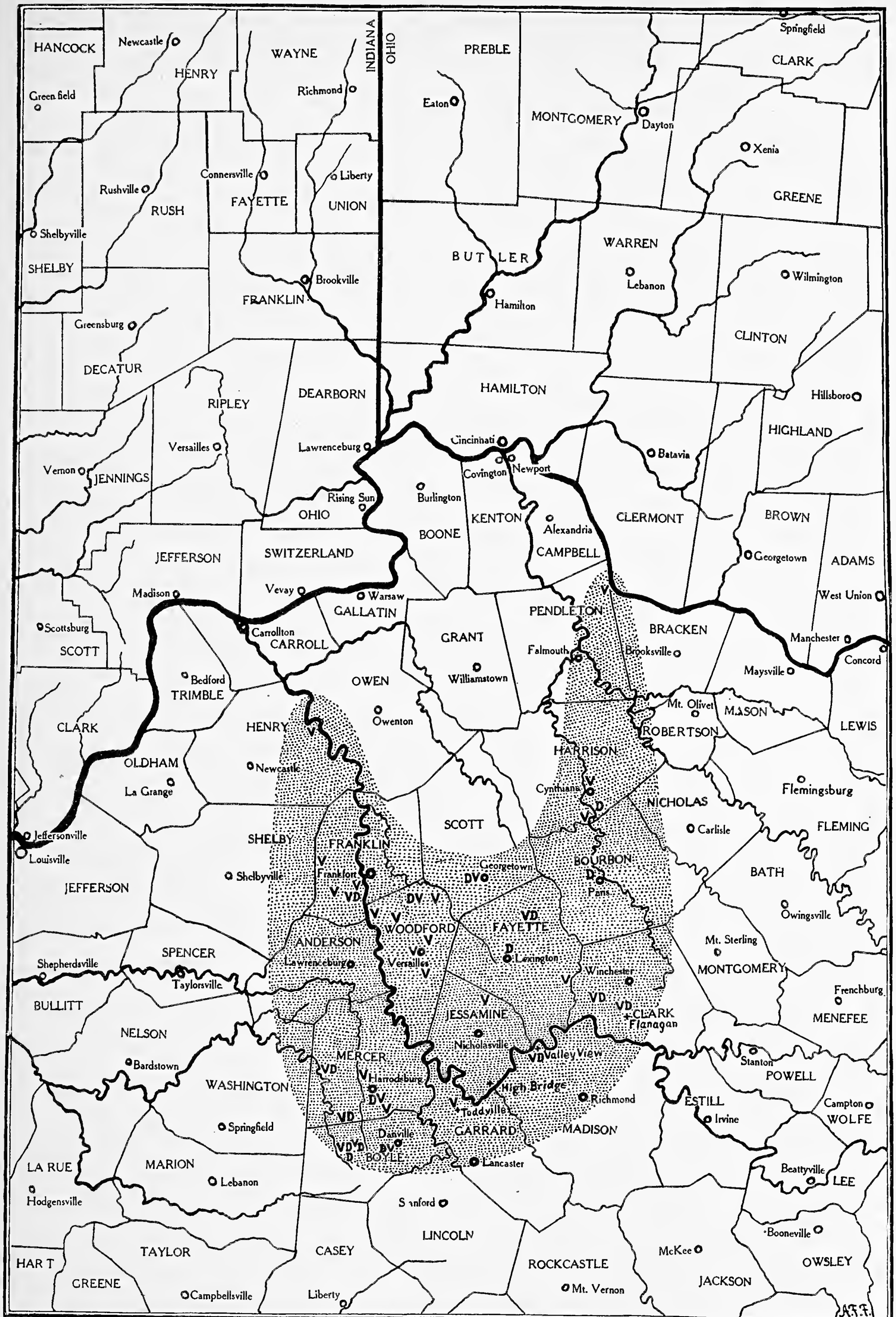
8
9 A
9 B
9 C
10

PLATE XII

Charts illustrating the distribution of various species of fossils.

The following charts indicate the localities at which various species of fossils actually have been found. The species are designated by the letters used. The number of localities indicated depends not only on the former distribution of the species in question, but also on the extent of the areas within which at present the containing strata are exposed and on the amount of field work done within these areas. The delimitation of various areas by means of dots and other devices is intended merely to assist the eye by indicating on which parts of the chart it is worth while to look for the letters indicating the presence of fossil localities. Since, evidently, the same strata must extend for many miles under cover, and since unquestionably their ranges frequently extended across areas from which the containing strata have subsequently been removed by erosion, these charts in no sense indicate the entire former distribution of the fossils under consideration, but only that part of this area at present accessible and within which the search for the species in question has been found successful. Moreover, since the writer has not had the opportunity of visiting more than a small part of the exposures easily accessible, sometimes only one or two localities in an entire county, it is evident that future search will much extend our knowledge of the geographical distribution of these species.

Plate XII indicates the distribution not only of *Strophomena vicina*, but also of *Dinorthis ulrichi*, which at numerous localities is associated with the former species, especially at the Cornishville horizon, but also occasionally near the base of the Paris bed.



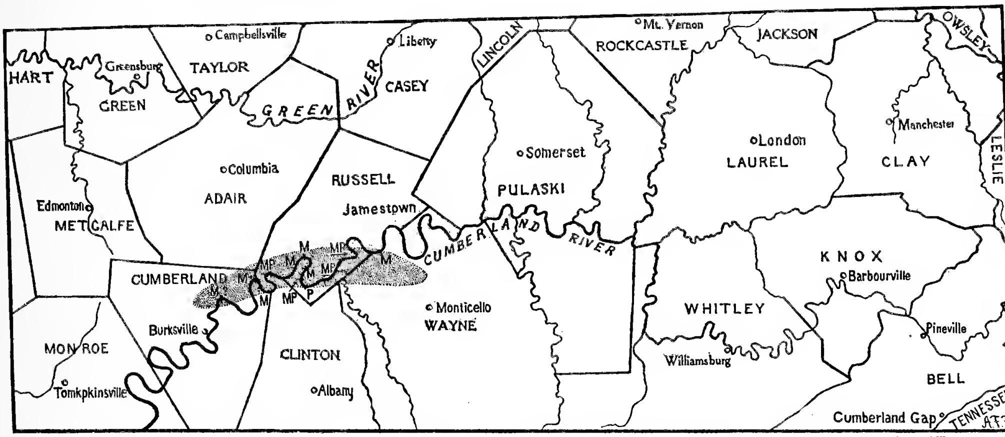
DISTRIBUTION OF STROPHOMENA VICINA (V) AND DINORTHIS ULRICHI (D) IN UPPER PART OF LEXINGTON LIMESTONE

PLATE XIII

The dotted area indicates the distribution of the localities at which *Strophomena hallie* has been found. The triangle within the limits of Madison county, Kentucky, indicates the only known locality for *Strophomena millionensis.* The limited area along the Ohio River, crossed by broken lines, includes the two localities at which *Strophomena higginsportensis* is known. *Strophomena hallie* and *Strophomena millionensis* occur in the Eden. The horizon of *Strophomena higginsportensis* is either the basal Eden or the underlying part of the Cynthiana formation.

DISTRIBUTION OF STROPHOMENA HALLIE (H), STR. MILLIONENSIS (M), AND STR. HIGGINSPORTENSIS IN THE EDEN AND CYNTHIANA BEDS.

DISTRIBUTION OF STROPHOMENA PLANOCONVEXA, STR. MAYSVILLENSIS, AND STR. SINUATA IN FAIRMOUNT AND MOUNT HOPE BEDS.



DISTRIBUTION OF STROPHOMENA PLANOCONVEXA AND STR. MAYSVILLENSIS IN FAIRMOUNT BED.

PLATE XIV

The dotted line includes the area within which *Strophomena maysvillensis* and *Strophomena planoconvexa* occur. The species are differentiated by the letters. The area covered by broken lines indicates the distribution of *Strophomena sinuata*, very imperfectly known at present.

PLATE XV

This plate is a southward extension of the chart included on Plate XIV, and gives the distribution of *Strophomena maysvillensis* and *Strophomena planoconvexa* along the Cumberland River, in southern Kentucky.

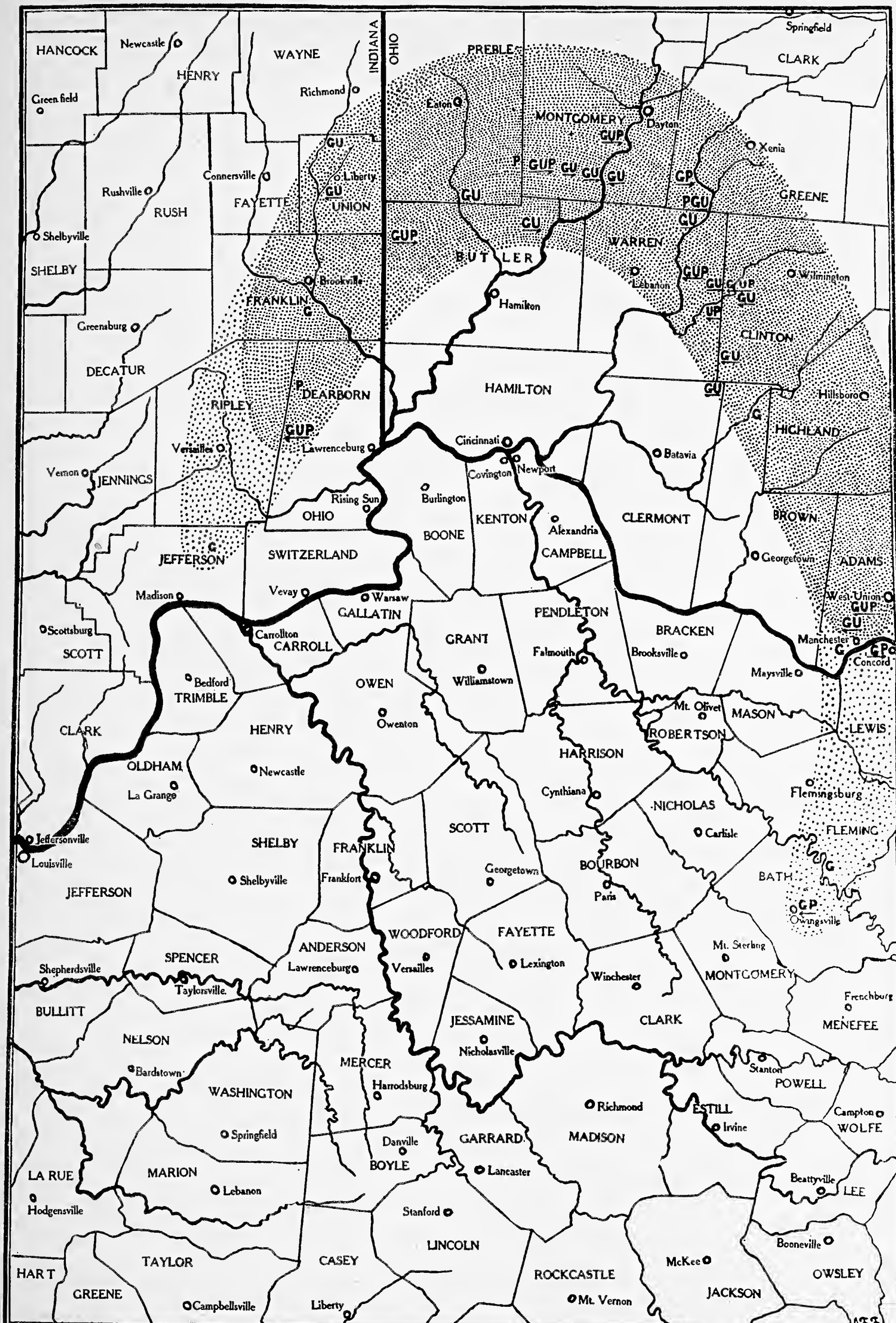
PLATE XVI

The geographical distribution of *Strophomena concordensis* at the top of the Arnheim member of the Richmond.

DISTRIBUTION OF STROPHOMENA CONCORDENSIS AT TOP OF ARNHEIM BED.

PLATE XVII

The dotted area indicates the region in which *Strophomena neglecta* and *Strophomena vetusta-precursor* are found. The more densely dotted part of this area gives the present known distribution of *Strophomena nutans*, which seems to have a more limited range.

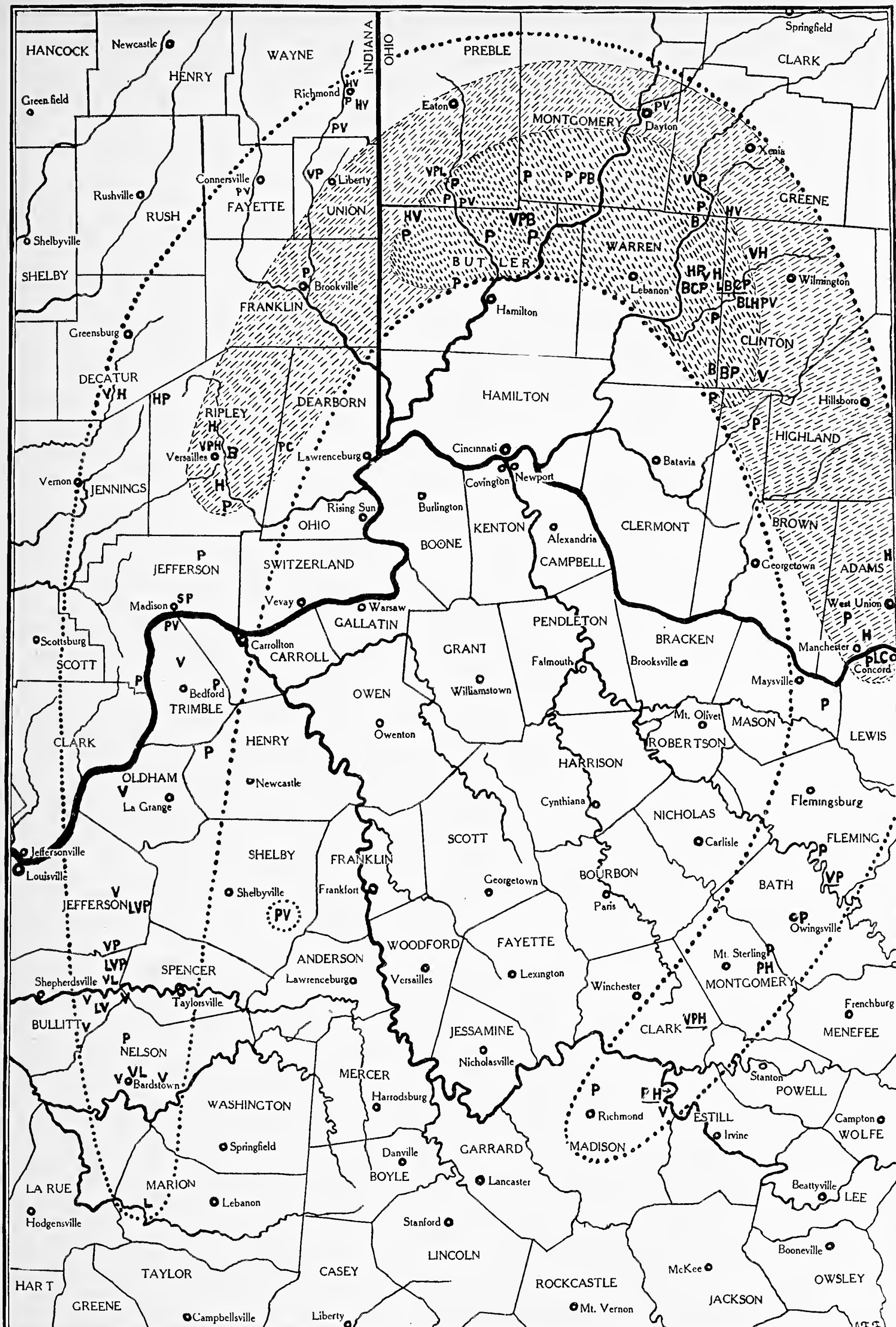


DISTRIBUTION OF STROPHOMENA NEGLECTA (G), STR. NUTANS (U), AND STR. VETUSTA-PRECURSOR (P) IN BLANCHESTER OR UPPER WAYNESVILLE.

PLATE XVIII

The known geographical distribution of *Strophomena sulcata* is indicated by the area included within the dotted line. The much more limited area covered by broken lines indicates the range of this species during Waynesville times. The lines directed diagonally upward and toward the left designate the area within which *Strophomena sulcata* has been found at the lower *Hebertella insculpta* horizon, at the base of the Blanchester division of the Waynesville. The extension of this area by diagonal lines directed upward and toward the right indicates how much greater is the known geographical range of this species during the Clarksville division of the Waynesville. The remainder of the space included within the dotted line indicates how much farther the known range of this species extends in the Liberty and Whitewater beds. In place of using a single letter to designate the locality at which *Strophomena sulcata* is known, the letter is varied so as to designate the horizon instead, in accordance with the scheme indicated at the base of the plate.

The distribution of *Strophomena vetusta* and of the various varieties of *Strophomena planumbona* is indicated by the letters *V* and *P* respectively.



STROPHOMENA VETUSTA(V) AND STR. PLANUMBONA (P) IN RICHMOND. STR. SULCATA IN WHITEWATER, SALUDA, LIBERTY, BLANCHESTER, CLARKSVILLE; AT BASE OF BLANCHESTER, ALSO IN CLARKSVILLE, IN HIGHER ZONES.

POPULATION CENTERS AND DENSITY OF POPULATION

FRANK CARNEY

GENERAL PRINCIPLES

It is a common observation that a very large percentage of mankind live in the lowlands, especially the lowlands that are not far vertically from sea-level. As population has become more dense in various parts of the world, man has learned to live under all kinds of topographic conditions, but primitive man was not a mountaineer. When people move into a new

country they are influenced by certain relationships of topography in locating their homes and their villages. Some general principles may be cited as representing these tendencies.

In the first place, all the great cities of the world today are either on the sea, on estuaries leading tidal-waters some distance into the land, or on the flood plains of rivers. In areas that are distant from the sea, the river-valleys usually determine where the early abodes are to be. Travel across continents is easier along the trenches that have been cut by the rivers; if a different course is required, the divides are chosen. A map of the Indian trails that the white men discovered in Ohio shows that the Indians followed the divides quite as often as the valleys; they wanted a lookout in their travels. This principle of river-valleys directing the early movements of men in Ohio may be illustrated by a study of the early cities of this state.

Again, we very often find man planting his abodes and developing his industry in areas marked by the confluence of river valleys, because, where streams unite, the flood plain is always broader, and the soil of the bottom land is richer. The early farms, therefore, can be larger and more productive. The most expensive farm land in Licking county is found in the very mature valley of what was probably the largest river that ever crossed central Ohio, a valley long out of use, except as portions of the present rivers follow segments of its course.

FACTORS IN THE LOCATION AND GROWTH OF POPULATION CENTERS

Early settlements in Ohio. During the early settlement of Ohio, the centers of population were very few and widely scattered. Invariably they were in agricultural regions. The pioneers of Ohio were farmers. These early farm locations, so far as was allowable under the conditions of the grants acquired by the land companies, were contiguous to routes that led the pioneers into the state. Of these routes, the Ohio river was the one that was most dependable all the year round; therefore, the location of the earliest farms in Ohio was often decided by the point at which the pioneer reached the Ohio river. If he came directly from the east, approaching the river from the present site of Pittsburg or of Wheeling, he was probably attracted by some of

the tributary valleys in that part of the state. If he came from the south by the old Wilderness road, from the Coast colonies, he probably crossed the Ohio at Maysville or farther west, and prospected northward through the valleys in that locality. The earliest party of all was attracted by the fertile lowlands where the Muskingum flows into the Ohio.

Almost contemporaneous with the founding of this agricultural colony, Marietta, was the planting of a colony at Columbia near Cincinnati, located conveniently on the Ohio, and adjacent to two broad fertile areas extending toward the north, the valleys of the Great Miami and the Little Miami rivers. The Scioto also attracted early settlers, but disastrous experiences with the Indians checked the founding of permanent settlements near its mouth, as well as at some other points along the Ohio.

Early importance of Cincinnati. The richest agricultural areas of the state, during the early decades of its settlement, were found in the southwest. The most rapid growth made by any town in the state was naturally associated with this center of agriculture. Accordingly, Cincinnati grew faster than any other of Ohio's pioneer villages. The reactions that always follow prosperous farming tended to make Cincinnati the metropolis of the state, and so long as Ohio was known to the outside world as purely an agricultural commonwealth, Cincinnati continued to be its leading city; when the dependence was placed later on other sources of wealth also, Cincinnati lost its position as the metropolis, giving place to Cleveland.

Zane's Trace. The condition which accounts for the settlement of agricultural areas extending north from the Ohio valley did not universally prevail during the pioneer days, because of another factor which came into operation when the Federal Congress decided to make a post-road across the state, from the vicinity of Wheeling to a point on the Ohio opposite Maysville, Kentucky. Zane's Trace started from opposite the present site of Wheeling, bore directly west to the vicinity of Cambridge, thence a little south to Zanesville, west again to Lancaster, thence south, crossing the Scioto at Chillicothe, and continuing southwestward to Maysville. This road led some pioneers to ignore the valleys, and to take up homesteads along its course. Accordingly, agricultural villages developed at an early date at the places named above. One other factor in the location of these villages is found

in the bargain which Engineer Zane made with Congress. He agreed to survey this line, on condition that he should receive one square mile of territory at each of the points where his line crossed the three rivers, the Muskingum, the Hocking, and the Scioto. Wilderness land was not then at a premium in the estimation of Congress, so, with the settling of a few other conditions, the bargain was completed, and Mr. Zane located the road. Immediately afterwards postmen commenced to ride through, and the first mail to cross the state went over this highway. The first town Zane located, he named after himself, Zanesville; the next was named Lancaster, and the third Chillicothe. It is interesting to study the influence of this trace (the Maysville Road, as it is sometimes called) on population in later decades; its effect is indicated in the decennial population maps.

Readjustments due to the canals. Later, centers of population developed for other reasons. The markets formerly had been reached by ox teams or horses, and, naturally, were limited. When canals commenced to operate, new places appeared on the map. The principles above stated, however, were still in operation, because the canals followed valleys, wherever possible. Villages were already scattered through the valleys. The influence of the canals was observed, however, in giving certain towns an advantage over certain other towns; for example, if, in a valley fifty miles long, there were three places of about equal importance, all reached by highways, and the business carried on by trucking, the particular town best situated, both in reference to the farm regions and the canal, soon had a handicap on the other two places.

The Ohio canal follows the Scioto from Portsmouth to Lockbourne; then it turns eastward into the old Newark river valley, which it follows to Hanover; from this point it continues along the Licking river to Toboso, thence it enters the Muskingum valley which it follows northward towards Akron, north of which its course is along the Cuyahoga valley to Cleveland. The Miami and Erie canal extends from Toledo, southward through Dayton, to Cincinnati. A few laterals from these canals reach territory east and west. But the day of the canal was short, because steam traffic on land was instituted not long after the canals were built, and railroads took the place of canals. The canal period, however, was long enough to change many ordinary towns into important cities.

Railways and population centers. Most of the early railroads of Ohio were responses to industrial needs outside of the state; the canals were entirely of local origin. Because of this fact, the railways took courses which were not always of the greatest convenience to Ohio. In the main, they were built to connect places on either side of Ohio, and they crossed the state more often at the convenience of the terminal points. Nevertheless, certain centers of population came into existence purely because of the railroads. The northern part of the state, the southern part, and later the central part, were crossed by railways. Somewhat later the interests of people in Ohio led to the construction of north-south railways, which proved a benefit to many towns that hitherto had been left aside, and brought into existence several new towns.

A railroad, topographically located, in passing through Licking county, must cross the immediate environs of Newark. The railroad entrances to Licking county, that is, the valleys, lead to Newark; therefore, Newark was destined by nature to be the most densely settled section of that county. At the confluences of valleys modern industry enlarges on the advantages that appealed to the pioneer; later, railroads converge at such points. The shipping facilities of such a location tend to make the population more dense. Newark has natural advantages which few other places in central Ohio possess.

Influence of political convenience. Another factor in creating centers of population is political convenience. To this factor Columbus owes much of its initial development. It is near the center of the state, is accessible physiographically, and therefore the correct location for the legal business of the commonwealth. But in the earlier decades, very few of the factors discussed above were operative in the development of a city at Columbus. Two other places were tried as the capital of Ohio, but, as settlements spread over the state, the location of the capital was changed because these places were not central.

In several counties of Ohio one wonders now at the location of the county-seats; they may be geographically central in relation to the highways of the county, and were probably convenient when the population was evenly distributed and travel was by horseback or in carriages. But recent decades have witnessed a marked redistribution of the population, and the construction of modern

transportation lines which make the county-seats relatively inaccessible. Some of the counties of the state are in a ridiculous condition in this respect. All the county business, the holding of courts and the paying of taxes, is done at a place which is inconveniently located so far as the great majority of the citizens of the county is concerned. The county-seat of Licking county is still logically placed; all parts of the county trend physiographically toward Newark, where nearly half of the citizens of the county live.

Arbitrary industrial purposes. Another factor in the development of centers of population is sometimes very important, but becomes operative later in the life of a commonwealth. When a more mature industrial stage is reached, congested centers may appear in spite of the location, and contrary to some of the principles already discussed. Barberton, in Summit county, in the last decade made a remarkable growth in consequence of a match manufactory. Other important population centers, illustrating the operation of this factor, are Depew, N. Y., and Gary, Illinois.

But while we find certain centers of population springing into existence in spite of the basal principles already stated, owing their origin entirely to an arbitrary industrial purpose, nevertheless, in the course of time such centers must stand the test of the basal principles.

The original highways, before canals or railroads came into existence, converged at valley junctions. In some instances, the enlarged industry of recent decades has built on the basis of population centers already in existence. Cases similar to Barberton, or Gary, Ill., are very rare, and are interesting in showing the stupenduous power of mature industry.

TYPICAL EARLY CENTERS

Cincinnati, the first manufacturing town. Reference has already been made to Cincinnati's early growth. The fertile farmlands back of Cincinnati made it a large city in the early days of the last century. In the Miami valleys abundant crops were grown, some of which were marketed down stream by boats. The farmers had money to purchase much-needed articles, but these were obtained with difficulty from the manufacturing centers of the Atlantic seaboard. The chief obstacle was the exorbitant price that was asked for goods which had to be carted across the Appa-

lachian mountains. Cincinnati, therefore, started early to manufacture the things demanded by the nearby farming industries. Thus the first manufacturing town west of the Alleghenys was created by home demands. More money came into circulation, and banking was shortly an important and necessary business. As a result of this early prosperity, a great amount of capital was available, and Cincinnati became an important center of long-distance business, in the first place by boat even to Europe, and later, when the canals were constructed, by the transportation of goods from the Ohio river to Lake Erie, via the Erie canal, to New York. Several factors gave Cincinnati an advantage over any other town of the state; the concentration of trans-Appalachian exchange through Cincinnati's banks for many decades is a matter to which we may not assign proper value. Banking business is generally conservative. Several old established banks of the Atlantic cities, which commenced early last century to place all their western exchange through Cincinnati, still continue to do so.

Chillicothe. In the early days of last century, one traveling overland from Cincinnati toward the sea, would probably have passed through Chillicothe. For several decades, Chillicothe was a very important place; agriculturally, it is more advantageously located than is Portsmouth, which is at the mouth of the Scioto river. The area of the lowland farming section increases from Portsmouth northward. The Scioto is a very recent stream geologically; for a long time antedating the glacial period, a great river, which had its origin in the Appalachian slopes of Kentucky and West Virginia, flowed northward, following in part of its course, what is now the Scioto valley, but in a reverse direction. Chillicothe lies in a mature part of that old valley, and the area of the good farmland decreases southward from Chillicothe.

Cambridge. Cambridge also, during the early decades, was a center of importance. It was located on Zane's Trace, the eastern part of which later became the National Road. During the stage-coach days, Cambridge was the first town of consequence to be met west of the Ohio. But when railways took the place of the slower methods of travel, Cambridge was not so favored; the through lines did not pass its way, and the advantages it had enjoyed in consequence of the former stage-coach traffic and the fairly good agricultural surroundings became relatively less and less important.

Cleveland. Among these early population centers mention should be made of Cleveland, though for a long time it was a place of little importance. It was at the mouth of a river, but the harbor was not inviting, and there was no distant trade that followed Lake Erie, no railways from the eastern end of the lake to transport goods to the big markets; it was not until the Erie canal was opened that Cleveland commenced to be much more than a village; in the decade, 1830 to 1840, its population increased 464.2 per cent. During the pre-canal period both Brooklyn and Newburg were larger towns, because they were situated on higher ground and were more approachable from the farming areas, south and west. Brooklyn particularly had a handicap on Cleveland in the river channel, which stood in the way of traffic from the west. Farmers on the east side of the Cuyahoga and a few miles south of the lake, in order to reach Cleveland, had to use a difficult roadway involving many long grades; it was much more convenient for them to transact their business on the top of the escarpment at Newburg.

With the impetus given lake trade by the facilities for freighting through the Erie canal, Cleveland at once became a transportation point both for goods from the east and for goods that the people in that locality wished to market, and this trade was further increased when the Ohio canal was opened. With this exchange, Cleveland commenced to grow, but Cleveland's growth, unlike that of these other places above noted, was not largely dependent on agriculture. Secondary industries, because of the shipping, became important early in the history of this town; chief among these was boat building. Goods for Buffalo and the other lake ports were shipped by boats, and the Cleveland shipyards foreshadowed the commerical future of the city.

With the opening up of the Ohio canal, a new source of industrial energy was attracted to Cleveland. South of Cleveland, it had long been known, the hills bore coal-beds, but there was no demand for coal in the little village at the mouth of the Cuyahoga, so there was no incentive to mine coal. When the Ohio canal reached Cleveland, insuring low freight rates, these coal mines at once were opened, and the cheap fuel brought to Cleveland led to the establishment of still other industries. Cleveland is not an agricultural city in its origin; it is a manufacturing city, always has been, and will probably never be anything else.

Northwestern Ohio. It was not till toward the middle of the last century that travel in the northwest part of the state became convenient. That was the last section to be settled, and, as a result, the centers of population elsewhere in the state had a decided start. Later, railways connecting the Atlantic seaboard and the west added to the prestige of Toledo. The extreme northwest corner of Ohio profited also by nearness to Michigan, the southern part of which was settled much earlier. These communities wished an outlet to the east, hence a railroad was built in 1836 from southern Michigan across the corner of Ohio to Lake Erie, and connected there with boat-freighting. For a long time Toledo made a very meagre growth, and Sandusky also grew slowly. The Miami and Erie canal made Toledo a shipping point for goods to and from the East, via Lake Erie.

The agricultural possibilities of the northwestern part of the state were early recognized, but the area was not attractive to the pioneer; it was famous chiefly for its marshes. To turn these marshes into farmland required great labor; the pioneer had not the conveniences for constructing effective ditches. For this reason the northwest part of the state did not attract the early farmers.

DENSITY OF POPULATION

What is over-population. All may not agree on an answer to the question, when is an area over-populated? Some hold that an area is over-populated when the inhabitants cannot get a normal amount of food; others, that over-population is reached long before that condition of stringency arises. We are under biological contract with destiny to make constant progress as a race; keeping the species in existence, is no guarantee of advancement. From this viewpoint, an area may be over-populated before its inhabitants cease to be properly nourished. When the struggle for physical existence monopolizes the attention of any part of the human race, that part cannot rise to higher planes. So long as man is becoming progressively more and more the master of his environment, the race is advancing. Poorly-fed peoples have never performed great engineering feats. Codes of ethics have never been evolved by starved nations. It takes prolificness in all ways to insure moral as well as material progress.

Types of over-population. There are two kinds of over-population, local and general. Some particular parts of a state may have too many citizens, whereas the state itself has room for many more. Particular states of a nation may be densely populated, and at the same time the general density of the whole nation fall far short of over-population. History records very few cases of general over-population, but there are numerous records of too great local density.

In the population records of some of the older countries, there are cycles which sometimes are so emphasized that we may misjudge the population capacity of the area under normal conditions. The occasional occurrence of famines in these countries, in which the mortality is very high, does not signify over-population; it means primitiveness in sanitation, and an ignorance of the cause of disease, a condition that is now approximated in the United States in particular diseases, such as typhoid fever, tuberculosis, and syphilis. In North America there are no records of famines or plagues since the white men commenced in earnest to take hold of the country; stories of famines among the Indians are current in legend, and doubtless such famines did exist.

Density in particular states. From the reports[1] of the last census it may be inferred that locally we are approaching a condition of maximum density. For example, Rhode Island has 517 people per square mile; Massachusetts has 420; New Jersey, 337; Connecticut, 230; New York, 191; Pennsylvania, 170; Maryland, 131; Ohio, 117; Illinois, 101. In Europe, Belgium has a population of 587 per square mile, and the Netherlands has 408; it is about two thousand years since Roman invasion brought this part of Europe in touch with the westward movement of empire. Less than three centuries have elapsed since a similar movement reached New England.

In the above list, with the exception of Ohio and Illinois, the more densely populated states are east of the Appalachians. Furthermore, they are in the northern section of the Atlantic states, and their density is due not to pastoral or agricultural but to manufacturing conditions. In western civilization maximum density or great density accompanies a strong development

[1] Henry Gannett, "The Population of the United States," *National Geographic Magazine*, vol. xxii, p. 36, 1911.

of the manufacturing industries. This fact is brought out better by the statistics of the percentages of urban population in the above states:

Rhode Island	68
Massachusetts	64
New Jersey	52
Connecticut	45
New York	69
Pennsylvania	39
Maryland	43
Ohio	37
Illinois	46

The order of population density in the first list of states is consecutive; but Maryland is the only state holding the same rank in the list of the percentages of urban population. New York has the largest percentage of urban population, while Ohio has the least.

Pacific coast states in last decade. During the last decade there have been some marked instances of rapid population growth among these states: Washington increased 120 per cent, Idaho 101 per cent, Oregon 63 per cent, California 60 per cent. In the seventeenth and eighteenth centuries a somewhat analogous condition might have been noted on the European side of the Atlantic Ocean, a condition that developed in accordance with Kingsley's slogan "Westward Ho," the industry and commerce of Europe spreading across the seas. In a few decades, at a rate which was marvelous compared with its unfolding in the old world, this movement crossed the United States. Considering the facts of this last decade, the future will witness a more equal division of commercial activity between the Atlantic and the Pacific.

The Pacific states have been sparsely settled for a long time. Nearly three-fourths of a century has elapsed since California took a foremost place as a wealth-producing state, but only in recent years has the area adjacent along the Pacific commenced to show its possibilities. While we have these large figures of population increase in the last decade, at the same time, the density of population in the respective states is not significant: Washington has a density of 17 per square mile, Oregon 7, California 15. The percentages of urban population are as follows: Washington 37 per cent, Oregon 31 per cent, California 45 per cent.

Nevertheless, this rapid growth of the Pacific states is due almost entirely to urban development; only a nominal gain represents the settlement within the last decade of certain well-watered farming districts along the coast and of other sections reached by the irrigation service.

The past, in building up industrial centers along the north Atlantic, produced the states having the greatest density in population, as well as the largest cities. The present, as an index of the future, shows remarkable virility among the Pacific coast states. The markets of the world, if markets are measured by population, front the Pacific; the major part of the world's population looks into the Pacific.

Industry and urban density. Industrial conditions are basal to urban populations. The particular industrial condition that accounts for the high general density in the north Atlantic states, as well as their great urban population, is the presence of water power for energizing manufacturing plants, and the proximity of coal fields. The coal fields of Pennsylvania have been very important in the industrial growth of these states; if the coal had been thousands of miles away, this area, even with its abundant water power, would not contain so many people, and certainly would not have so many large cities; nor would the United States have its present rank among the nations, for the industrial progress of the whole country has fluctuated with that of the Atlantic states.

The limit of rural density. Commencing with the period of settlement, for several decades, according to the decennial statistics of the United States, there was a marked growth of population in the rural districts. Later these districts came to a static condition; then, urban population began to increase, and the gain in population thereafter depended upon the growth of the cities. Thirty or forty years ago the rural population of Ohio had become static, or in a few counties had commenced to decline. Under the prevalent methods of agriculture, the state had reached its maximum in rural population, and its cities, excepting a few, had not yet experienced the modern expansion of manufacturing.

In the last census the term "rural population" includes all villages having less than 2500 inhabitants. Thus "rural" includes slightly more than the farming population.

From 1900 to 1910 the rural population of the state as a who le

declined 1.3 per cent; the percentages of decrease in particular counties were large: Brown, 12.1; Crawford, 11.3; Jackson, 14.3; Meigs, 13.2; Monroe, 13.8; Paulding, 17.4; Pike, 13.5; Vinton, 14.6; Van Wert, 10.4. Only one of these counties, Crawford, gained in gross population; this gain was due to the growth of its only city, Bucyrus.

In certain other counties a marked gain was made in rural population: Athens, 20.1 per cent; Belmont, 31.1; Cuyahoga, 29.6; Guernsey, 13.3; Jefferson, 47.5; Mahoning, 13.8; Summit, 20.1. Each of these counties contains one or more prosperous cities. The population growth of these cities in the particular counties is as follows: Athens county, Athens, 78.1 per cent; Belmont county, Martins Ferry, 17.6, Bellaire, 30.6; Cuyahoga county, Cleveland, 46.9; Guernsey county, Cambridge, 37.4; Jefferson county, Steubenville, 56; Mahoning county, Youngstown, 76.2; Summit county, Akron, 61.6, Barberton, 116.1. This urban activity increased the demand for farm products, which may partly account for the gain in rural population. In the vicinity of the larger cities intensive methods of agriculture are being practised.

Much of the central Mississippi basin during the last decade has shown very slight, if any, gain in population; many of the states have not shown any increase because agriculturally, under the present methods of farming, they have been fully exploited, and the industrial readjustments have only begun to develop manufacturing centers which in time will be large cities. Were it not for the city of Chicago, Illinois would now be in the stagnant class; omitting Chicago, the state has made no growth since 1900.

Urban density in Ohio. The effect of urban concentration appears in the rapid growth of certain cities during the last decade. In New York state the increase of urban population was 42 per cent, and of rural population 2 per cent; in Massachusetts the urban population increased 32 per cent and the rural 4 per cent; in Ohio the urban 48 per cent, while the rural declined 1.3 per cent. There is something significant in the figures of these three states. Industrially, if the growth of urban population is an index, Ohio leads these states in the progress made from 1900 to 1910. Ohio has five cities of over 100,000 in population: Cleveland, Cincinnati, Columbus, Toledo, and Dayton. There

are only two other states, Massachusetts and New York, that have five cities in the 100,000 class. The United States has fifty cities in this class. In the whole country, during the last decade, fourteen cities were added to the 100,000 list. Of the cities thus advanced, some of them present surprising figures: Birmingham, Ala., for example, in the decade ending 1910, increased 245 per cent; Los Angeles, Cal., increased 212 per cent; Seattle, Wash., 194 per cent; Spokane, Wash., 183 per cent; Portland, Ore., 129 per cent; Oakland, Cal., 124 per cent.

During the last decade, Cleveland gained 46.9 per cent, Cincinnati 11.6 per cent, Columbus 44.6 per cent, Toledo 27.8 per cent, Dayton 36.6 per cent. Municipal patriotism is always concerned in these decennial statistics. There is much geography also in these statistics. The growth of Columbus is interesting; its central position in the state, and the ample transportation facilities attract manufacturing.

Ohio's smaller cities. In the list of cities ranging from 25,000 to 100,000, Ohio has nine, as follows:

	INHABITANTS	RATE OF INCREASE IN LAST DECADE
Akron	69,067	61.6
Canton	50,207	63.7
Hamilton	35,279	47.5
Lima	30,508	40.4
Lorain	28,883	80.2
Newark	25,404	39.9
Springfield	46,921	22.7
Youngstown	79,066	76.2
Zanesville	28,026	19.1

The smaller cities of the state have shown the greatest growth in the last decade; this is natural. When a city attains the size of Cleveland, Columbus or Cincinnati, it does not make in a decade such a phenomenal growth as is possible with smaller places. Competition is more rife in these larger centers, and manufacturers looking for places to locate plants, often prefer the smaller places.

Akron, Canton, and Youngstown are along the neck of an hourglass-shaped area of relatively dense population joining Lake

Erie and the upper Ohio basin. In this region are several other cities which contain over 10,000 population. Geographically that is the liveliest part of Ohio; it is the area to which profit accrues directly and indirectly from the ore and steel business, connecting the Superior mines and western Pennsylvania. Active trade routes are not in operation long before population centers commence to appear along them.

In the next decade, this hour-glass region of Ohio will make just as rapid progress as it has in the last; even if the conditions basal to its industry were changed, its present business momentum would continue several years. But this region is liable to suffer with the decline of the steel business in western Pennsylvania, in case its cities are slow in making the necessary readjustments.

In addition to the cities already mentioned, Ohio has four others, East Liverpool, Mansfield, Portsmouth, and Steubenville, each of which contains between twenty and twenty-five thousand in population; also 18 cities each having between ten and twenty thousand; and 42, ranging from five to ten thousand in population.

PROBLEMS OF LARGE CITIES

Markets and urban density. The concluding part of this discussion has to do with particular problems that are associated with centers of dense population. In large cities markets are generally found; in smaller towns only stores. The market is a response to the advantage of eliminating the greatest possible number of middlemen who stand between producers and consumers. In the market usually the producer and consumer come face to face, the man with the hoe and the woman with the basket, and they discuss prices. Wherever population is congested the most important question of all is food, its quantity, quality, and price. The market helps to keep prices moderate. The chief market-buyers are laboring people and a small percentage of middle folk, the sturdy people of some means, who believe in saving if they can, instead of buying everything over the telephone, and paying the added prices. The market and itinerant hucksters are essential to the welfare of industrial centers. It is important that the actual necessities of life be reasonable in price, because the major part of the population in every large city consists not of bankers, merchants, and professional men, but of laborers.

Water supply and urban density. Each year cities are becoming more concerned over problems of sanitation. Municipalities are not proud of invalids and paupers, even though these figure in census reports. A most important source of disease in cities is the drinking water; the chief duty of municipalities, therefore, is to supply its citizens with pure water. But in practice this duty is not usually recognized till some hygienic disaster arises or till a shamefully high death rate compels them to consider the question of a source of pure water or modern means of purifying the water. The source of the water is some assurance of its condition when it reaches the consumer, but it is no guarantee; filtering and constant vigilance in guarding against organic contamination are necessary.

Sewage disposal and urban density. In most American cities there is opportunity for improvement in the matter of sewage disposal. The prevalent method appears to consider but one object, that is, to get the sewage out of sight as speedily as possible, regardless of the contamination of rivers and other water bodies from which drinking water is secured. Such methods contrast badly with the accomplishments of our civilization in engineering. Many years ago, a citizen[2] of Cleveland read a paper before the Western Reserve Historical Society, in which he discussed with almost prophetic vision this question as related to his city. At that time the Cuyahoga valley proper and all its tributaries were used as outlets of sewers, and the river was left to remove the sewage.

Urban transportation. Congested centers of population should have ample facilities for traveling quickly, conveniently, and cheaply about the city; with speed, because time is valuable; at a reasonable charge, because the laboring people who must go to their work should not be expected to contribute large dividends to transportation companies. Rapid urban transportation of the most modern type does not exist in any Ohio city. A few cities in this state are already so large in area that rapid-transit, preferably by subways, is imperative.

[2] John H. Sargent, *Western Reserve Historical Society,* Tract 82, p. 295, 1891.

THE CLIMATE OF OHIO

FRANK CARNEY

If you have always lived in what men generally call a good climate, by which, as a rule, they mean uniform conditions of weather, you are as unconscious of it as of the involuntary actions of your body. If, however, you live in a different sort of climate, you are more or less aware of and concerned in the weather changes that may have to do with your whole livelihood. Ohioans sometimes complain very much about the weather, but they are proud of their climate. The term weather refers to the details which, combined, make climate. The sunshine of today and the clouds of yesterday are features of the weather; the general conditions throughout the month or year, or during a long term of years, make up the climate.

There are three important factors in climate: temperature, precipitation, and wind or air pressure. Secondary features associated with some of these three frequently attract much attention. If the temperature is intensely low or intensely high, it may serve to characterize the whole climate, regardless of the

other features. If the precipitation throughout the year is fairly high but all falls in a particular month instead of being distributed with some uniformity through the twelve months, the region may be a desert. If the wind blows always from one quarter instead of varying as it does in Ohio, disagreeable features may be said there to characterize the climate.

TEMPERATURE

As influenced by latitude. Temperature depends very largely on latitude. The latitude regulates the area covered by a unit sunbeam. A sunbeam of a given cross-section area, when the sun stands directly over the equator, will cover on the equator an equal area, but at that same instant, in our latitude, the same area of sunbeam may be spread over twice as much land. In the former case, the energy of the beam is concentrated; in the latter, it is scattered. The sunbeams, passing through the atmosphere, we are told, do not warm the atmosphere, but the temperature of a land area appears to be connected very closely with the temperature of the atmosphere. The atmosphere, therefore, must get its warmth from another source than the sun's rays which pass directly through it. This other source is radiation from the surface of the earth. Sunlight warms the land and the water surfaces, which radiate their heat and warm the atmosphere. Consequently, in those parts of the earth where the sunbeams are more vertical, the surfaces are warmed more, and through radiation the atmosphere adjacent is also kept warmer. In our latitude we never have vertical sun rays, but throughout the year the degree of obliqueness changes very much.

Furthermore, our highest temperatures do not come when the position of the sun gives the least oblique rays, for the reason that the general temperature depends also on the gradual warming of the atmosphere by the continued radiation of surface heat. As a result, the climax of summer is not in the mathematical middle of the summer months, but lags behind; and our lowest winter temperatures follow the middle of the winter months.

During May, we note that the heat received in a particular day by a given area in this latitude is not entirely radiated during the following night. Next morning a slight increment of the previous day's warming remains, and to this will be added the

increment of tomorrow and the next day, so that by the middle of August the land of Ohio is quite warm; for several weeks after the sun's rays become more oblique the atmosphere keeps its summer heat, simply because it is being added to by heat radiated from the land.

As influenced by altitude. Another factor in temperature is altitude. All places on a given parallel do not have the same temperature. A plateau two thousand feet high, adjacent to a lowland belt, will give different readings of a thermometer than will the lowland at the same time of the day. In Ohio the variation in altitude is not sufficiently great to show very marked temperature differences through this factor.

As influenced by bodies of water. A third influence, bearing on temperature, is found in the relationship of land and water areas. This follows from these two forms of matter having different specific heats. Lake Erie and an equal area of the state of Ohio exposed to the same insolation during the same length of time will show different heat results. It takes longer to warm or to cool a body of water, but when its temperature is once changed it remains constant much longer than does an equal area of land. During the winter a water body stores up a great deal of low temperature, which it gives off slowly, and as a consequence keeps the nearby atmosphere cold in the spring, whereas the atmosphere over the neighboring land has already become balmy. Similarly, in the fall the water bodies, having stored up a great amount of summer heat, give it off slowly and keep the air over the adjacent land still moderately warm, while in areas farther away the temperature has already grown cold. A practical result of this last condition is shown in the land areas adjacent to water bodies being devoted to fruit growing, because in the spring the cold of the lake keeps the buds from starting, and the time of late spring frosts has passed before they bloom; in the fall the warmth of the lake retards early frosts, and the fruit has ample time to mature.

Isothermal maps. Men have devised a method of expressing some of the facts of temperature. A temperature map of Ohio during any particular year consists of isotherms, which connect places having the same mean annual temperature. An isothermal map of Ohio, therefore, shows variation, because Ohio stretches through a few degrees of latitude. The range in mean annual temperature varies from six to seven degrees.

PRECIPITATION

There is always moisture in any natural atmosphere, but in order that we may observe this moisture it is necessary that the atmosphere be cooled. A warm atmosphere holds its moisture. An atmosphere at any temperature holds some moisture, that is, it is practically impossible to take all the moisture out of an atmosphere. The form in which precipitation falls depends upon the temperature; below freezing, it comes as water in crystal form; at other times as rain; at still other times, under proper conditions, it collects invisibly, forming, if this collection is kept up long enough, a dew or frost.

Quantity. The quantity of precipitation is in itself not the most important factor about precipitation. For all practical purposes, especially for agriculture, we are concerned more with the seasonal distribution of this precipitation. An area during the year may have forty inches of rain and yet have that rain so distributed seasonally as to make it impossible to grow crops.

Another feature of the atmosphere's moisture is of interest physiologically. An atmosphere which continues to hold a great deal of moisture becomes oppressively humid, and makes work disagreeable, particularly in warm weather; in cold weather, it intensifies the effect of low temperatures.

Seasonal distribution. In Ohio we are interested in precipitation in one other particular. The unequal distribution of rainfall and snowfall gives rise to floods. The earth is not able to soak up the moisture as fast as it comes, and the moisture has to run off. Along the Ohio river this is a matter of industrial concern. Shipping conveniences make it necessary for men to have wharves and buildings well out on the stream. A sudden change of twenty or thirty feet in the depth of that stream necessarily causes loss. If the sudden flood depth is unannounced, disasters follow; the government, therefore, under the direction of the Weather Bureau, times the progress and intensity of these floods, and has made arrangements for keeping the people downstream informed; thus they have an opportunity to protect their property.

A long period of either rain or drought, between early spring and fall, is detrimental to farming interests. Almost every year in some sections of the state, the farmers suffer loss either through

too much or too little rain. But a record of crops for a series of years shows that no particular part of Ohio has any advantage over other parts, in this respect.

WINDS

Someone once said, and the assertion has been current through the centuries, "The wind bloweth where it listeth." The physics of the atmosphere was not well understood in Biblical times. The atmosphere moves according to law. In Ohio we are in the track of a very regular wind belt, the "prevailing westerlies." If the wind always blew from the west, it would grow very monotonous, but the prevailing direction may be from the west and yet a good many variations be introduced. These variations from the prevailing wind give the most interesting phases of this subject.

Cause of air currents. As to their origin, winds are classified under two heads, "highs" and "lows", the names having no connection with their velocity. The atmosphere moves not because there is any external force which gives it impulsion, but because of its tendency to maintain equilibrium. The fluctuation of wind direction represents the effort of the atmosphere to return to a state of equilibrium. There has been an unbalancing somewhere in its body, and the atmosphere is on the move, trying to establish a condition of rest; the unbalancing is due to a difference in the relative weight of adjacent parts of the atmosphere.

The reason why the atmosphere does not, at all places, have a uniform weight is closely connected with the question of heat-radiation from the earth's surface; there may be other causes, but this is known to be one. Take the roof off an ice-house, sweep the sawdust away, and you will cool the nearby atmosphere. That atmosphere, growing cool, becomes heavier; adjacent to it is lighter atmosphere, which the heavier atmosphere displaces. That is the principle of the winds. Somewhere the atmosphere has become heavier and it pushes out; or somewhere the atmosphere has grown warmer and consequently lighter, and it is displaced by the heavier. The movement arising from either cooling or warming is an effort to establish equilibrium. The weather in Ohio, in its variations from day to day, is largely connected with this question of atmospheric density, or high and low pressure areas.

An area of high pressure means that there the barometer registers more than normal. It signifies heavier atmosphere; that heavy atmosphere will move outward, displacing lighter atmosphere. If Columbus is the center of such a high pressure area, over the neighboring land surface the atmosphere is moving outward. A low pressure area signifies atmosphere which is lighter than normal. At some distance from such a center, the atmosphere is always heavier and consequently is moving towards the center upward from which the lighter air is rising.

Weather conditions about cyclonic and anti-cyclonic centers. These storm centers, anti-cyclonic (high pressure) and cyclonic (low pressure) areas, sometimes are very large, not infrequently having a diameter several times that of our state. In that case, the movement of the atmosphere on the surface involves several degrees of latitude, and a corresponding change in temperature so far as it is influenced by latitude. A current of air moving southward from the anti-cyclonic center, warms as it goes; growing warmer, it can hold more and more moisture; consequently, the sky will be clear in the path of the atmosphere which moves southward. According to the same principle, a current of air moving northward from the storm center grows cooler, its moisture commences to show in the sky as clouds, and with further cooling precipitation falls.

With a low pressure area central at Columbus, the atmosphere from all directions moves towards that city. Atmosphere coming from the Kentucky side moves into higher latitude and accordingly is cooled, with clouds and precipitation in that part of the storm area. But atmosphere moving from the northern part of the state to lower latitudes, warms as it goes, and is able not only to hold its own moisture, but to acquire more; on that side of the cyclonic area there will be clear sky.

Over the center of the high pressure area the atmosphere is settling or descending; this increasing pressure keeps the temperature warm or at least constant, hence the sky is clear; whereas at a cyclonic center the air is rising and expanding; thus it cools and precipitation falls.

On account of the earth's rotation the surface air currents about these "high" and "low" centers do not move in a straight line, but are diverted constantly to the right, as they move, in this hemisphere, and to the left, south of the equator. When we

make a plot of the actual movements of the winds of a cyclonic or of an anti-cyclonic area, the diagram resembles a spiral rather than the spokes of a wheel.

Furthermore, these centers are not stationary; they move toward the east. The storm path may have a northern or a southern component in its direction of travel, but the prevailing direction is eastward. The frequency of these storm paths in Ohio increases northward across the state. A large part of the state, however, may be affected by a cyclonic or an anti-cyclonic area whose center takes a course through Lake Erie or even in Canada.

Thus about either of these centers, "high" or "low," we find a variety of conditions: a variation in the thermometer readings, in the register of the barometer, and in the precipitation. A vertical plane drawn through a cyclonic or an anti-cyclonic area in any direction and studied in detail, will emphasize this variety. Because of this fact, Ohio has a variable and interesting climate; the changes are sometimes sudden, but the disagreeable weather does not endure.

Other air currents. Associated with the proximity of land and water bodies are other atmospheric currents, locally important. These are called "land breezes and sea breezes," but in Ohio we find a corresponding phenomenon along Lake Erie. During the period of sunshine the land heats more quickly than does the body of water; the radiated heat warms and consequently lightens the air above the land; the heavier air above the water moves inland, establishing a cool lake breeze. In the late afternoon, the water becoming relatively warmer, a flow of air from the land is established, making a land breeze. In the course of a day the bottom and the walls of a valley are differentially heated, instituting movements of the atmosphere similar in origin to land and sea breezes. It is on this principle that we are advised nowadays never to build houses on the valley bottom nor on the top of a hill, but some distance below the hill top or crest of a ridge; in this location the extremes of heat and cold are more moderate.

CLIMATOLOGY

Our Government excels all others in the scientific study of the climate; nevertheless we have a paucity of students of clima-

tology, however contradictory these two facts may appear to be. Germany probably has the most thorough record-investigators of climate, but the German government does not do for this science what our government is doing yearly. Our Weather Bureau is the envy of all students of climatology. Facts pertaining to weather data have right of way on the telegraph wires of this country for a certain period every day. In European countries, where militarism usually can accomplish arbitrarily what it wishes, they have not yet been able to secure for weather data the necessary special privileges in the telegraph system. The United States can marshal an array of weather data for a given period of years that is not equalled by any other government.

Early development in America. No discussion of climatology in the United States, and especially a discussion that pertains to the Buckeye State, is complete without alluding to the fact that the first weather maps issued in this country were published at Cincinnati. Cleveland Abbe, the leading American student of climatology today, aided by the Cincinnati Chamber of Commerce, in 1869 instituted the first weather service. Through certain voluntary efforts of associates, Mr. Abbe collected data as near and as far from Cincinnati as he could get it, and on the basis of this data he published information about the weather. The following year the Federal government organized a national service under the War Department. In 1891 this meteorological work was transferred to the Department of Agriculture, as the Weather Bureau. Cleveland Abbe has been associated with American climatology from its beginning; the work he did while Director of the Cincinnati Observatory gives the subject special historical interest.

WEATHER BUREAU SERVICE IN OHIO

The three districts. Our state is divided into three sections, the Northern, Middle and Southern. By defining the Middle section we have the others properly distinguished. The northern margin of the middle section begins on the east with the northern boundary of Columbiana county, and follows due west the nearest county line, ending with the northern boundary of Van Wert county; the southern margin starts with the northern boundary of Monroe county, and proceeds westward to the northern boundary

of Preble county. In a rough way, these are latitude divisions, and as such are pertinent to any study of the weather.

Period of observations. Meteorological work proceeds from observations, usually instrumental, therefore accurate, not approximate. Few people can guess within several degrees the temperature at any given time. We have in Ohio two classes of weather observers, one salaried, the other volunteer; only in connection with the Weather Bureau stations are men employed on salary. It is a praiseworthy fact that in some places records covering nearly a century's observations, at least on temperature and precipitation, are available. In the following places weather data have been tabulated for the number of years designated:

LOCATION	TEMPERATURE	PRECIPITATION
Northern section		
	years	*years*
Bangorville, Richland county	24	24
Bowling Green, Wood county		30
Cleveland, Cuyahoga county	40	40
Hudson, Summit county		50
Oberlin, Lorain county	28	36
Sandusky, Erie county	34	34
Toledo, Lucas county	40	50
Wauseon, Fulton county	41	39
Middle section		
Bellefontaine, Logan county	17	32
Columbus, Franklin county	33	33
Granville, Licking county	25	29
Ohio State University	28	28
Sidney, Shelby county	23	28
Urbana, Champaign county	15	43
Southern section		
Cincinnati, Hamilton county	39	40
Dayton, Montgomery county	38	30
Hillsboro, Highland county	12	32
Marietta, Washington county	67	91
Portsmouth, Scioto county	80	80
Waverly, Pike county	28	

Weather Bureau stations. In each section the government maintains also regular Weather Bureau stations. In the Northern section there are three: at Cleveland, Sandusky, and Toledo; in the Middle section a station is maintained at Columbus; in the Southern section, one at Cincinnati.

The value of a volunteer observer's data depends on his training and the instruments he has at his disposal. As a usual thing, the Federal government does not send out a very complete equipment of instruments to be handled by a volunteer observer. The regular Weather Bureau stations record very complete weather data; they measure the precipitation, tabulate the wind direction and velocity for every minute of the twenty-four hours of the day; tabulate the periods of sunshine and cloud during the day; record the dates of appearances of frosts, and the velocity of particular storms, if unusual. Much of this is done automatically. Man is not sufficiently discerning or accurate to do some of these things; instead he has invented machinery that will do the work correctly.

Illustrative records. The volunteer observers report periodically to a Weather Bureau station. The data collected by the larger number of people who are working just for the love of it, together with the data of the regular stations, characterizes the weather of Ohio, and for the period concerned is a basis for describing its climate. The results may be illustrated by reference to particular weather phenomena for a given period. For the year that closed in December, 1910, the mean annual temperature in the Northern section was 49.1°; in the Middle section, 50.6°; in the Southern section, 52.6°; for the whole state, 50.4°. But these facts are of little value unless we have some average or normal with which to compare the data. The normal temperature for the Northern section is 50.1°; for the Middle section, 50.9°; for the Southern section, 52.9°; for the whole state, 50.7°.

The weather of Ohio, as already stated, is not monotonous; comparing one year with another we note the variation. The mean annual temperature in 1909 for the three sections and the whole state, in order, was 49.4°, 51°, 53.4°, and 50.9°. Last year was cooler than usual, while the preceding year was more than usually warm.

But there is another fact always of great consequence in temperature conditions, that is, the temperature range. In 1910, in

Ohio, there was a temperature range of 125°. The physiological effects of being transferred suddenly through such a temperature range would be bad; but the extremes are in different seasons. August 17, 1910, at Vickery, the official thermometer registered 100°. On February 19, 1910, at Bladensburg, the official thermometer registered −25°. The temperature range the preceding year was only 117°; the highest temperature, 97°, being noted at New Alexandria, July 30, while the lowest temperature, −20°, was recorded at Bellefontaine, December 30.

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THE TWENTY-FIFTH ANNIVERSARY OF THE FOUNDING OF THE DENISON SCIENTIFIC ASSOCIATION

On the evening of April 12, 1912, a special meeting of the Denison Scientific Association was held in commemoration of its twenty-fifth anniversary, Prof. Theodore S. Johnson presiding. The following program was arranged for the occasion: "A statistical study of the contributions published in the Bulletin of the Association," Prof. Frank Carney; "Greetings from the Board of Trustees of the University, and reminiscences of C. L. Herrick," Prof. A. D. Cole; "The early years of the Association," Mr. Wallace H. Cathcart; "The Foundations of Culture," Prof. C. Judson Herrick.

In opening the exercises, President Johnson explained the purpose of the Association in the life of the college, commenting felicitously on its sustained growth and the present outlook.

Dr. Carney reviewed, by tabular classification, the contributions of the several laboratories to the sixteen volumes of the Bulletin published by the Association. When Clarence Luther Herrick, founder of the Association, established the Bulletin, but two departments of science were maintained by the University, Natural History and Physics; in a short time the former was divided into Geology and Zoology; for many years the courses in Botany and Chemistry were given by the professors of Geology and Physics respectively; a department of Botany was organized in 1904, of Chemistry in 1905; partly for these reasons there is considerable range in the number of contributions by the several laboratories.

The Board of Trustees was represented by Prof. A. D. Cole, head of the department of Physics at Ohio State University, who for several years, while professor of Physics at Denison, was an active member of the Association, and for a period acted jointly with C. L. Herrick in editing the Bulletin. Professor Cole expressed the greetings of the Trustees, and their satisfaction in, and approval of, the Association's activities. The greater part of his time was given to a narrative of incidents connected with the work of C. L. Herrick during the early period of the Associa-

tion, illustrating the remarkable energy and optimism of its founder.

Mr. Wallace H. Cathcart of Cleveland, also a member of the Board of Trustees, was a charter member of the Association, and a student of C. L. Herrick. His interesting reminiscences relating to Professor Herrick disclosed an alert and sympathetic appreciation of the work of this great teacher whose contagious enthusiasm has withstood the twenty-odd years which Mr. Cathcart has given so largely to business affairs.

The Association meets every two weeks during the college year, the program consisting of two five-minute section reports, and one paper, each from a different department. The subject matter presented is grouped under the following heads: (1) Botany, (2) Chemistry, (3) Engineering, (4) Geography and Anthropology, (5) Geology, (6) Mathematics, (7) Music, (8) Physics, (9) Zoology.

THE FOUNDATIONS OF CULTURE[1]

C. Judson Herrick

In my childhood days I used to hear about Johnnie Apple-seed, a quaint old character who went about visiting village schools and seeking opportunity to talk to the children. He took his name from a habit of collecting apple seeds and dropping them into the ground as he went along, to raise fruit trees for future generations. His dry humor and homely precepts unquestionably helped many a school child on his way, and doubtless many of these children in later life tasted of the fruit from trees planted by the wayside by Johnnie Apple-seed. But he left no lasting impress upon the educational institutions of his time, and of the few trees of his planting which struggled through neglect to frowzy maturity, probably very few ever bore really good apples.

Johnnie Apple-seed's method was not very efficient, when measured by the standards of modern horticulture. The scientific culture of fruit trees and other farm products has long since passed the haphazard stage. Not only do we preserve and improve the physical value of the land by fertilizers, rotation of crops, etc., but the character of the vital stock itself is improved by prolonged systematic experimentation and by constant attention to selective breeding. Our government agencies in America are annually expending millions of dollars in experimental farming. But in some respects our educational system seems scarcely to have passed beyond the stage of haphazard planting.

The problems of education resolve themselves into two chief factors: first, the native endowments with which the child comes into the world; and second, the process of cultural modification by which these endowments are brought to the highest attainable efficiency—or briefly, nature and nurture. From the circumstance that the latter factor is obviously more directly under the teacher's control than the former, it has naturally followed that

[1] An address delivered at Granville, O., April 16, 1912, at the special exercises in celebration of the Twenty-fifth Anniversary of the founding of the Denison Scientific Association.

practical educational work has centered almost exclusively about problems of nurture. Our entire educational system apparently developed upon the assumption that the child comes to school with no educational capital at all and that it is the function of the school to add to nature's physical endowment such mental and moral superstructure as the consensus of educational wisdom has decreed is best for mankind, the individual's welfare not being taken into account, except as he is one unit in a homogeneous mass.

In higher educational work we have in some measure advanced beyond this mechanical process of squeezing all men's minds (and all women's, too) into a single preformed mold by forcing them all through the same prescribed course of study and throwing out as defective or incorrigible all who cannot be made to fit without too great pressure. But in the elementary and secondary school the stuffing and squeezing process often goes on about as mechanically as in a brickyard.

Let us look into this thing from the genetic standpoint. In the matter of origins, the poet tells us that

> Not in utter nakedness,
> But trailing clouds of glory do we come
> From God who is our home.

On the other hand, it is charged against the biologists that by their emphasis on the descent of mankind from brutes they are dragging the race down from a position "a little lower than the angels" to a stage but little higher than the monkeys.

I do not feel myself competent to present a scientific defense of all parts of Wordsworth's "Intimations of Immortality," and yet I do not think that one violates the spirit of his reflections in maintaining that a critical examination of all the data regarding the evolution of man shows very clearly that the best as well as the worst elements of human character strike their roots downward into the common biological soil. This is not to deny that through many of the blind gropings of childhood, through

> Those obstinate questionings
> Of sense and outward things,

there shines a light of heavenly origin; for

> Heaven lies about us in our infancy.

But the biologist would suggest that most of these heavenly influences have reached the child life through the medium of an indirection, like rain from above upon the biological soil from which that child life has sprung.

In short, if the doctrine of evolution has any value at all in the study of human origins (and we must conclude that it has), then it must be frankly and honestly accepted just as far as known fact demands. It must be pushed to its limit or it breaks down utterly; for its fundamental principle is the law of continuity of process in nature. The interruption of the process at any point breaks the chain and leaves in our hand only the useless fragments of discredited theories. And if evolution be one of the basal cosmic laws, as I believe it is, it is inconceivable that it should break down at the finish.

One of the saddest chapters in the history of human thought is the story of the half century of conflict between theological intolerance and scientific narrowness following the publication of Darwin's *Origin of Species*. This era is happily past and there remains now merely the task of the articulation of all knowledge from whatever sources derived, into a unitary scheme of things. Many of our ablest naturalists have been unable to see beyond the limits of their own fields of endeavor. Even Mr. Huxley, in the ripest years of his life, was inclined to draw a sharp contrast between what he called the cosmic process and the elements of social and ethical progress. He says, "The cosmos works through the lower nature of man, not for righteousness, but against it." And again, "The ethical progress of society depends, not on imitating the cosmic process, still less in running away from it, but in combating it."

Doubtless much harm has been done to sound science by ill-advised attempts to derive all higher social and ethical institutions directly from "ape and tiger methods" of evolution. But this "gladiatorial theory of existence" is not the whole of the cosmic process, as Huxley seems to imply. "The history of civilization," he says, "details the steps by which men have succeeded in building up an artificial world within the cosmos." This is a very remarkable statement to come from the greatest champion of modern evolutionary theory; for by what right does he separate human civilization from the rest of the cosmos? This civilization has grown up, not apart from the process of nature, but within it,

and failure to recognize this elementary principle has wrecked many a promising sociological and ethical enterprise.

An examination of the behavior of many lower animals (birds, for example) presents us with many instances of tender care of offspring and mates, of the delicate attentions of courtship and of heroic self-sacrifice, which cannot be distinguished objectively from altruism, parental love and other noble mental qualities of mankind. By what right do we admit the derivation of malice and avarice from brutes and deny this in the case of love and altruism? And love and altruism are as essential adaptive qualities in the elaboration of the higher social fabric of civilized human communities as are parental care and self-sacrifice for the preservation of a bird community.

And now, returning to our point of departure, let us inquire again what it is which the normal child brings with him into the world? First, there is a sound body, whose perfection of form and function is the direct product of the survival of the fittest and the elimination of weaklings during countless ages of past evolutionary history of the "ape and tiger method."

Then, there is a large collection of inborn instincts, the time and manner of whose successive appearance is predetermined by the hereditary organization of the child's nervous system. These instincts are, like the body, products of the operation of natural biological laws. It is a common idea that animal conduct is regulated by instinct, while man is controlled by reason. Nothing could be farther from the truth. How far animals are guided by reason, I am not now prepared to say; but it is certain that James is correct when he says that no animal possesses so many instincts as man himself. These instincts are often masked or supplanted early in life by acquired intelligence and so are commonly overlooked.

In the third place, the child is born with the capacity for individuality in his further mental development, an ability to profit by experience (his own and his elders'), or briefly, docility. All three of these are native endowments and, within rather wide limits, are common to all members of the race. The general bodily form and the pattern of instinctive behavior run quite true to type in all members of a given stock; but the capacity which I have termed docility is much more variable. And, aside from this congenital diversity in intellectual capacity among

the members of a given child population, still more variety is introduced into the problem by the fact that all truly intellectual attainment, as distinguished from the innate instinctive pattern, must be individually acquired, and its character will depend wholly upon the personal experience of the child himself and the nature of the environment within which this experience must be gained.

The structural basis of this three-fold inheritance is very plainly seen in (1) bodily configuration; (2) the inherited form of brain and its internal web of nerve cells and fibers, which provide a fixed mechanism, common except for minor variations to all members of the race alike, for the performance of their common instinctive actions; and (3) the large association centers of the brain, the exact form of whose internal organization is not wholly predetermined at birth, but is shaped for each individual separately during the course of his growth period by the process of education to which he is subjected.

This third element is by no means a new structure in the human brain. It has been my task for many years past to study the evolutionary history and primeval sources of these correlation centers as they are found in the lower animals. It is found that this tissue is present in all lower vertebrates and that its amount is directly proportional to the intellectual capacities and docility of the animals exhibiting it. In the nobler species of animals and in man it does not replace the lower reflex and instinctive mechanisms, but it is superposed upon these. None of these higher associational (intellectual) activities are possible, except through the mediation of the lower or instinctive centers. Neurologists, accordingly, now distinguish an old brain (palæencephalon), which is common to all members of the vertebrate branch of the animal kingdom, from a new brain (neencephalon), which is practically coextensive with the cerebral cortex. The new brain, with its functions of correlation, is really as old, so far as its first beginnings are concerned, as the old brain; but, whereas the latter attains its full development as a reflex and instinctive apparatus in the lowest mammals, the former continues to increase in size and importance and it is still increasing in the civilized human races today.

The kangaroo is one of the lowest types of mammals. A kangaroo with a body weight of about 100 pounds has a brain weigh-

ing a little less than 2.5 ounces (64 grams in Macropus rufus, see *Ziehen* in Bardeleben's *Handbuch der Anatomie*, 1903), or a ratio of brain to body weight of 1 : 711. In the human race this ratio is 1 : 42. The average brain weight of European men is about three pounds (1353 grams), the brain being 21 times as heavy as that of a kangaroo of about the same body weight. This increase in the weight of the human brain is almost entirely localized in the association centers of the cerebral cortex and structures immediately dependent upon them, the old brain remaining on practically the same level as in the kangaroo, except for the actual reduction in man of some of the simple sensory apparatuses, notably the centers for the sense of smell.

An exhaustive study of all that we know of the evolution of animal behavior (including animal intelligence) and of the evolution of the brain shows that throughout the history of animal development these two processes go hand in hand, viz., the development of increasing complexity of the reflex and instinctive life, with a parallel elaboration of the old brain, and, on the other hand, the development of higher intellectual capacity and docility, with the elaboration of the new brain, or cerebral cortex and other parts directly connected therewith. This relation, we may be sure, is no accident.

Now, our educational systems in general have recognized that the child brings into the world no *mental* endowments ready-made—no knowledge, no ideas, no morals. These have to be developed anew in each generation under the guiding hand of education, for they are the functions of those association centers whose nervous pattern is not fully laid down at birth, but must be elaborated slowly during the plastic growing years by personal experience. This lesson we have learned and learned so well that we devote one-third of the average span of life of our most promising youth to the educational training necessary to ensure the highest possible development of the latent cultural capacities of these association centers of the cerebral cortex.

But we, as educators, have too often been blind to the further fact that the child brings something with him into the world in addition to the unformed plastic materials of his association centers, viz., an immense capital of preformed and innate ability, which takes the form of physiological vigor and instinctive and impulsive actions, performed for the most part automatically

and unconsciously. This so-called lower or animal nature is ever present with us. In infancy it is dominant; childhood is a period of storm and stress, seeking an equilibrium between the stereotyped but powerful impulsive forces and the controls of the nascent intellectual and moral nature; and in mature years one's value in his social community life is measured by the resultant outcome of this great struggle in childhood and adolescence. This struggle is education.

The answer to the riddle of life, however, lies not in a successful attack upon the native innate endowments of the child, which Mr. Huxley would apparently call his inheritance from the cosmic process, directed toward their destruction and replacement by "building up an artificial world within the cosmos." No, that would be unbiological and wasteful, for our world of ideas and morals is no artificial world within the cosmos, but it is a natural growth, which is as truly a part of the cosmic process as are "ape and tiger methods" of evolution. No higher association center of the human brain can function, except upon materials of experience furnished to it through the despised lower centers of the reflex type. So also, no high intellectual, aesthetic or moral culture can be reached, save as it is built upon the foundation of innate capacities and impulses.

We are gradually learning through the kindergarten that the most economical way to lead a child into the realm of learning is not to stamp out all of his natural interests and shut him up with his face to the wall, while he learns by rote an a-b-c lesson which is neither interesting nor useful. On the contrary, we accept as given his native impulses and automatisms, his spontaneous interests and his over-production of useless movements, and we use these as the capital with which we set the youngsters up in the serious business of the acquisition of culture. But how does it happen that we make so small use of the principles here learned in the later years of the child's schooling?

Not all of the instincts with which man is by nature endowed come into function in a sucking babe or a kindergarten pupil. Childish curiosity is our strongest ally, if only we can use it wisely, throughout the whole of the educational career from infancy to the graduate school. Anger is a mighty passion in childhood. It is not wise to eradicate it altogether; rather keep it, though under curb, for there are times when real abuses arise, which

require that the man know how to hit and to hit hard. And so with the instincts of self-preservation, of fear, of sex—these all have their parts to play in the nobler works of life and are by no means to be eradicated. The ascetic ideal of mortification of the flesh as a means of grace is fundamentally wrong in principle. Our case calls for no blind, indiscriminate attack upon the world and the flesh, but rather the subjugation and discipline of these, so that we may use them effectively in our attack upon the devil.

Conflict is inherent in the cosmic process, at least in the biological realm, from beginning to end. There is the struggle for physical existence among the animals. And even in the lower ranks of life there arises also the struggle within the individual between stereotyped innate tendencies or instincts and individually acquired experience. This is clearly shown by experiments on animals as low down as the Protozoa. And out of this inner conflict or dilemma intelligence was born. With the gradual emergence of self-consciousness in this process, arises the eternal struggle with self, that conflict which leads to the bitter cry, "When I would do good evil is present with me." Conflict, then, lies at the basis of all evolution, and the factors of social and even of moral evolution can be traced downward throughout the cosmic process.

The social and ethical standards, therefore, have not arisen in opposition to the evolutionary process as seen in the brute creation, but within that process. And our immediate educational problem is the elaboration of a practicable system of public instruction which can use to the full the enormous dynamic energy in the hereditary impulsive and instinctive endowment of the child and build upon this, in the form best suited to the respective capacities of all the separate individuals, a properly ordered sequence of studies which will develop the latent capacities of each pupil and ensure a vital balance between the strong, blind impulse of the innate nature and the acquired intellectual, aesthetic and moral control.

No single curriculum can be devised which will solve this problem. The pupils enter our schools with a wide range of hereditary endowments on the instinctive plane, with great diversity in their potential capacity for learning, and from very diverse home environments, whence by far the larger part of their "social heredity" must be derived, that influence of example

and unspoken precept which is of greater educational significance than the sum total of formal schooling. This diversity in endowment, capacity and environment must be reckoned with in our educational system. Our present custom of herding together all of the children of a given age is an injustice to all of them.

It is probably true that from 5 to 10 per cent of the children in the public schools of our large cities, for one reason or another, fail to derive much benefit from the ordinary grade work, and Dr. Gould is of the opinion that about 50 per cent of city school children are below a desirable norm of health. In the New York and Boston public schools it is estimated that about 1 per cent of the total school population is sufficiently defective or subnormal to make their segregation in special classes desirable. In Boston these defectives have for a number of years been taught in special classes in which the individual needs are closely studied. The result is that the normal children are not retarded by their slowness, and, on the other hand, by skillful special training the laggards are greatly improved, instead of being lost from school altogether, as otherwise often happens. A definite series of psychological tests has been devised by which doubtful cases can be analyzed, to determine whether the mental development of the child is progressing at the normal rate as compared with his physical development. In smaller towns and villages it is not often possible to grade the children so closely; but in nearly all cases it is at least practicable to break up each of our present grades into two sections, A and B, containing respectively the better and the poorer pupils, the A section completing the assigned work of its grade and being promoted to the next grade in advance of the B section. This plan is working well in many schools.

The first and most obvious practical step in carrying out such a program is a proper medical inspection of all school children. In cities where this inspection has been given a fair trial it has from the start justified itself on economic grounds by the check placed upon the spread of contagious diseases in schools, and at the same time it has revealed some surprising conditions.

The public school teacher's greatest problems are usually the dull or incorrigible pupils who never reach full efficiency and usually drop out in the lower grades. In a very high percentage of these border-land cases actual physical defects are found whose removal restores the child to the normal at once. And where the

defect is irremediable, this should be recognized and special provision made for the child accordingly.

From 3 to 20 per cent of the children examined in the public schools are found to have defective hearing, though the defect is unrecognized in the vast majority of these cases, with the result that an otherwise normal bright child is regarded as hopelessly stupid. It is estimated that 30 per cent of the children in the New York public schools are from one to two years behind their proper classes and 95 per cent of these backward children are so principally because of defects of eye, ear, nose or throat, which could easily be detected and remedied through effective medical inspection. Such neglect is nothing short of criminal.

Opportunity for vocational training should be provided in all public schools. The State freely educates at great expense the few who expect to become physicians, lawyers, and teachers. Why should it not give similar vocational training to the many who are to become mechanics, clerks and book-keepers? The great majority of our pupils leave school at the close of the grammar grades or earlier. The following year or two is a critical time in the life of a boy. Given at least the rudimentary knowledge of a trade and an interest in it, and the victory is more than half won. During these years his earning power is small and he is apt to drift aimlessly from one petty job to another. For this period continuation part-time schools of technology should be provided and the employer should be required to allow all minors between the ages of 14 and 18 a few hours of daylight in which to attend such schools until they become proficient enough to earn a full day's wage at their chosen trades or callings.

Much progress has been made in various communities along lines similar to these, and we may look forward to a further broadening of our educational system so as to come into still more efficient and intelligent contact with the great vital interests of the community, and so, after planting our educational seed in the school, we shall ensure by suitable after-culture a more healthy crop of men and women.

In all this we take the child as he is given to us, and after a careful analysis of his endowments and capacities endeavor by skillful guidance to assist in the formation of character. We cannot create that character; we can only help the child to build it for himself. But does our educational responsibility end here?

Shall we continue to accept the hereditary endowment of the child as the gift of God, and in consequence feel ourselves absolved from any further responsibility?

The past half century has seen a very fundamental change in the human attitude toward many similar questions. Not many years ago, when pestilence stalked through the land, it was generally accepted as a divine punishment for sin and the nation was bowed down in abject humility and repentance. Today we likewise recognize the penalty for sin; but our repentance comes to expression in the form of active sanitary precautions. We drain our swamps, screen from mosquitos and flies, vaccinate our children and safeguard the purity of our milk and water supplies.

But how slow we are to learn from any experience but our own. In the smiling valley which lies before us, we persist for more than fifty years in fouling the sources of our water supply with sewage. Must we wait until we too suffer the inevitable epidemic of typhoid fever before we profit by other towns' experiences in exactly similar cases and build our sanitary sewer?

The future of our race is in God's hand; but he has entrusted to us as a community a very large part in working out our destiny, just as he has placed a large measure of responsibility for individual culture in your hand and mine. The experience of the race has shown that the advance of culture in every civilized country is accompanied by a very grave peril.

The transfer of the evolutionary process from the biological to the social plane, from the process of the elimination of the physically unfit by natural selection to the process of the preservation of all individuals under the guidance of the few members of the community who are preëminently fit to be social and moral leaders—this change in the evolutionary process opens the way for grave abuses. Those who are intellectually preëminently fit and morally unfit become a positive menace. And the whole process of socialization of racial ideals tends toward the weakening of the physical stamina of the individual. These problems have not been solved, but enough has been done to show that the solution lies within our grasp.

In France the birth rate has actually fallen below the death rate and in the other most highly cultured portions of Europe and America the trend is in the same direction. Nevertheless, since 1880 the American death rate per 1000 population has been

reduced about 25 per cent, and this reduction is sure to continue with the diffusion among the people of better sanitary and medical knowledge. But the birth rate has fallen off even more rapidly and the percentage of defectives has increased.

This is the great problem of the twentieth century—eugenics. It is by no means insoluble and we already have the data necessary to make great progress. Our knowledge of human heredity is well advanced. We know, for instance, that certain defects, like congenital deaf-mutism, will reappear in every generation as a family trait when two deaf mutes marry; but, on the other hand, this defect can be bred out of a family by suitable crosses with family lines in which it is unknown. The extreme forms of degeneracy, like feeble-mindedness, are distinctly hereditary. In one case on record, in a single family of 319 members many died in infancy, and of the surviving children 119 are feeble-minded and only 42 are sufficiently near to normal to be able to care for themselves. In such cases, all of the children should be kept under surveillance and prevented (by committal to institutions, if necessary) from the inevitable propagation of their defects which results from intermarriage with their own kind.

Dean Sumner, of the Protestant Episcopal Cathedral of Chicago, has recently announced that he will in the future solemnize no marriages save in cases where both parties bring a certificate from a reputable physician of freedom from certain physical and mental taints. This marks one of the greatest advance movements of our time, and the day should speedily come when the matter of the granting of marriage licenses will be placed by the State in the hands of an expert medical board. Today we examine and license all applicants who wish to run an automobile or a pedlar's wagon, but make the assumption of the responsibilities of matrimony a subject for flippancy and jest.

These are simply illustrations of practical movements which can be begun at once, to ensure the improvement of our hereditary racial stock. The whole matter of "National Vitality, its Wastes and Conservation," is discussed in a comprehensive way in the Bulletin of the Committee of 100, published by the Government Printing Office at Washington in 1909.

President Taft, on the 9th of this month, signed a bill creating a Children's Bureau in the National Department of Commerce and Labor, which is destined to play a large part in the future

protection of the child in this country. There is at the present time a bill pending in the National Congress, creating a Department of Public Health, the Owen Bill, which has the support of the leaders of medical, philanthropic and social progress. It should be passed at once. As an illustration of the practical import of such legislation, it may be mentioned that our present pension roll of over $150,000,000 per annum is three-fourths of it due to illness and death from diseases that were preventable. We are building the Panama Canal under the direction of our War Department economically and well because we first controlled the sanitation of the Isthmus. All are agreed that without such sanitary control the task would be as impossible for us as it was for DeLesseps.

The hope of the future conservation of our national vitality lies in the presence in every community of centers of liberal learning and research like this college and this Scientific Association, where the scientific foundations of future success in this great movement are laid, and intelligently trained exponents of these principles are scattered throughout the community to give practical demonstration of the true course of right living.

But this movement for the conservation of national vitality is not something which we can leave to government, philanthropic, educational and other public agencies. Each one of us has his part to play, a part which is vital to our present and future national life.

The greatest single factor which is now operative to lower vital efficiency in such a cultured community as this is the artificial strain of high pressure living, which is now all but universal in all urban communities. This pressure arises, not as in former times from the struggle for bread, for mere subsistence, among the very poor. On the contrary, its most acute form is seen among the rich and the well-to-do. The struggle for wealth, for recognition and for social position has replaced with us the struggle for existence. This strain is felt not only by the men of big business and large professional responsibilities, but also by their wives and daughters, whom we are apt to think of as coddled in the lap of luxury. Our very play has come to be a most exhausting kind of work.

There are few cultured families in America where the blighting influence of business, professional or social excess is not evident.

It saps the foundations of personal health, of happiness and of family life. In its train follow neurasthenia, insanity, sterility. The health, the sanity and the enduring life of the individual and of the nation depend upon an immediate and thoroughgoing reform in these respects.

In conclusion, I wish to repeat that our highest intellectual, aesthetic and moral culture springs directly from the same vital stream as our sanity of body and mind; and He who announced that He came into this world that we might have life and have it more abundantly devoted no small share of His labors to repairs upon the biological foundation which is so necessary a basis for the elaboration of the higher life.

DRAINAGE CHANGES IN THE MOOT'S RUN AREA, LICKING COUNTY, OHIO[1]

HARMON A. NIXON AND DEXTER J. TIGHT

INTRODUCTION

Evolution of glacial theories, as applied to Ohio's drainage systems. One of the problems that early attracted the attention of our first State Geologist, Prof. J. S. Newberry, and his assistants, after the organization of the permanent Geological Survey of Ohio in 1869, was the problem of establishing the relationship which existed between our present drainage systems and the drainage of Ohio before the glaciers of the Pleistocene period advanced into the area and deposited their load of drift. After a little more than three years of investigation, they published, along with other results, their tentative solution of this problem. From a study of Professor Newberry's work[2] in the Cuyahoga River Valley and its vicinity, and of E. B. Andrews' investigation[3] in the southeastern part of the state, we find that they are

[1] This paper is a report on investigation carried on under the direction of Professor Carney, of Denison University, to fulfill requirements in Courses 9 and 10 of the Geological Department.

[2] *Geological Survey of Ohio*, vol. ii, 1874, p. 444.

[3] *Ibid.*, vol. iii, 1878, Report on Richland, Knox and Licking Counties, pp. 310-361.

agreed that so far as these areas are involved, the gross features of the topography are the same today as before the glacial invasion. Not more than a year later M. C. Read[3] suggests the theory, based upon his work in Richland, Knox and Licking Counties, that the drainage lines of Central Ohio have taken their present alignment chiefly through glacial influence. This theory of the dual origin and difference in age of the streams of the central portion of the state, as compared with those of the other divisions, has been supported by leading geologists up to the last decade. The work of Professors Tight[4] and Bownocker,[5] of J. H. Todd[5] and Gerard Fowke,[5] has tended to substantiate Read's theory as it applies to Southern Ohio, and the work of Tight,[6] and Leverett,[7] in its relation to Central Ohio.

General discussion of drainage changes. However, within the last decade, investigations in the central part of the state, carried on for the most part under the Department of Geology of Denison University, have tended to show that a large portion of this area has derived its drainage features from preglacial influences. This theory of the age and origin of the streams of the central portion of the state seems to be more in harmony with the supposed origin of those of the southern, eastern and northern parts of the state than the hypothesis formerly so widely accepted.

Scheffel concludes in his paper, "Drainage Changes near Granville, Ohio,"[8] that the stream reversals in that section, so commonly attributed to glacial intervention, antedate the invasion of the Pleistocene glaciers and are probably due to diastrophic movements. Mather[9] has concluded from a study of the lacustrine deposits and terraces at Claylick and its vicinity that the cutting of the Licking Narrows and the consequent capture of the west-flowing Newark River by the present Licking River is not due to a stoppage of drainage, ascribed by Tight[10] and Leverett[11] to the advance into the area of the Illinoian ice sheet, but

[4] *U. S. Geological Survey,* Professional Paper No. 13, 1903, p. 108.

[5] *Ohio State Academy of Science,* Special Paper No. 3, 1900, Bownocker, Todd and Fowke.

[6] *Bull. Sci. Lab., Denison Univ.,* vol. vii, pt. ii, 1894, p. 49.

[7] *U. S. Geological Survey,* Monograph xli, 1902, p. 196.

[8] *Bull. Sci. Lab., Denison Univ.,* vol. xiv, 1909, pp. 157–174.

[9] *Ibid.,* pp. 175–187.

[10] *Loc. cit.,* p. 49.

[11] *U. S. Geological Survey,* Monograph xli, 1902, p. 155.

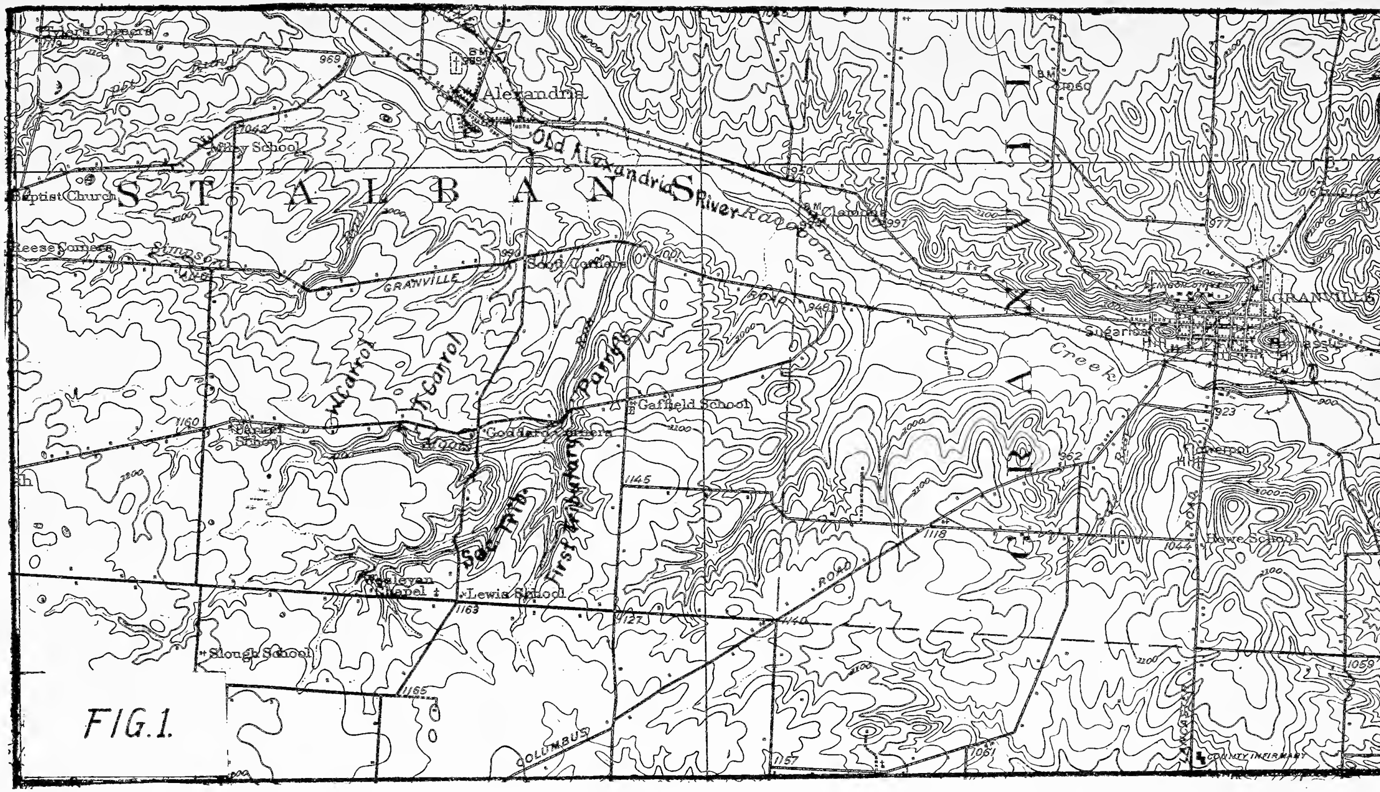

S T. A L B A N S
G R A N V I L L E
Alexandria
Old Alexandria
Raccoon River
Granville
Sugar Loaf
Creek
Clemons
Gaffield School
Goddard Corners
Lewis School
Wesleyan Chapel
Slough School
Baptist Church
Reese Corners
Tyler's Corners
Lowe School
Granville Road
Columbus Road
County Infirmary
Simpson
First Tributary Parnell's
Sec. Trib.
Carrol
McCarrol
Soott Corners

FIG. 1.

is due to a differential tilting during the late Cretaceous, or Pliocene period, which was characterized by such movements. This can safely be correlated with the movement to which Scheffel refers, we think, because they were both locally confined, the tilts were in the same direction, and both took place at about the same time.

As a result of these and similar investigations in the state, there is a tendency among students to take the view that glaciation has not been the important factor in the diversion of streams and alteration of drainage systems which it was considered a few years ago. However, in all probability, the change of drainage which we describe in the present paper was due primarily to glaciation.

Drainage Changes in the Moot's Run Area

Detailed description of Moot's Run and its tributaries. The problem which forms the subject of this discussion is connected with the upper course of Moot's Run. This stream lies in St. Albans Township, flowing, throughout most of its course, parallel to the Raccoon and in the same direction. This portion of the stream is about two miles directly south of Alexandria. At Parry's, a half mile west of the Gaffield School,[12] the stream turns directly north, and thence flows in a fairly straight course to the Raccoon.

Certain phenomena noted in the course of this stream suggest that it is not such a one as would be developed in an age of normal erosion. These phenomena are:

1. Just south and west of Parry's a valley three-eighths of a mile in width suddenly narrows to a rock gorge 240 feet in width, a condition not found in normal erosion in a region of homogeneous rock texture and structure.
2. A repetition of the above phenomenon at the source of the second tributary of Moot's Run.
3. The axes of Moot's Run and the main portion of the second tributary are parallel to the axis of the drainage divide on the south; thus Moot's Run and its second tributary flow parallel to the divide instead of away from it.

[12] All of these points may be located at once by referring to the accompanying topographic map.

Discussion of drainage factors, as applied to this area. Scheffel has well explained in his paper, "Significance of Drainage Changes near Granville, Ohio," that there are three important factors which may interfere with or influence the normal development of a drainage system: piracy, diastrophism, and glaciation.

That glaciation has been the chief factor in the development of the Moot's Run area is proved, we believe, by evidence of both a positive and negative nature. That there have been reversals of drainage, even a superficial examination will show. Let us consider in their order the influence of these three factors on the drainage development of the area. In the paper referred to above, Scheffel roughly groups the various forms of piracy under three heads: those due to topography, to stratigraphy, and to rainfall.

Inadequacy of piracy, to account for these changes. The first is the form that is found under normal erosion. By the cutting back of its own headwaters one stream captures the headwaters of another, thus diverting a greater or less portion of its drainage system. That such has taken place in this region is inconceivable. There is no evidence of a contest between rival streams for supremacy in this drainage area. There is no well defined divide, which is usually present in such an area, and, what is more to the point, the streams which now occupy this area could not have accomplished the excavation of the present gorges, a task which the theory of piracy would assign to them. Since this is the case, we need not dwell on the other causes of piracy, a differentiation in the structure and tilt of the rocks, or a differentiation in the distribution of rainfall over the area, neither of which has been operative in this section of Ohio.

Inadequacy of diastrophism, to accomplish these changes. Since diastrophism has been so strongly urged as the chief influence in the drainage diversions of an adjoining region, its operation in the Moot's Run area might be anticipated.

Imagine a mature drainage system, with a medium-sized stream occupying its basin, into which several low gradient tributaries flow; this fairly represents the old Alexandria River and its tributaries. Now imagine a gradual tilting of the land along a north and south axis in the neighborhood of Alexandria, a mild rise but sufficiently rapid to prevent the stream from maintaining its direction by degrading its bed. What change in drain-

age would result in such a case? This question Scheffel has answered in the paper referred to above. By a differential movement of the rock a new divide was formed east of Alexandria. This resulted in a reversal of drainage, and we have the anomalous condition of a stream, with a wide mature valley at its headwaters, flowing eastward through a narrow, constricted channel at Granville.

One might immediately infer that this is the exact condition which we have in Moot's Run area. Is the reversal of drainage not due to the same diastrophic cause? We would give a negative answer, for several reasons:

1. If Moot's Run had been a normal tributary to the old Alexandria River, joining it in the vicinity of Alexandria, and this tilt had taken place, it would not have been sufficient to cause Moot's Run to adopt a course parallel to the Raccoon, and with the same direction of flow.

2. There are, however, very substantial reasons why this diversion of Moot's Run cannot be correlated with the diastrophic movement that produced the narrow section of the Raccoon Valley at Granville. An examination of the well records at the houses along the road just to the north and parallel to Moot's Run shows a slope of the rock floor to the west for over a mile. These records are as follows: At the temporary bench mark, one-half mile south of the Gaffield School, the bed rock surface is 1125 feet above sea level; at T. Carrol's[13] it is 1065 feet above sea level; at W. Carrol's its altitude is 1075 feet. It is evident, from a comparison of these heights above sea level, that the rock surface slopes slightly to the west, and has done so ever since pre-Pleistocene times. Hence the diastrophic movement to which Scheffel refers was not sufficient to divert Moot's Run into its present channel.

3. A proof, sufficient in itself to controvert the theory of diastrophism as applied to this area, is the fact that Moot's Run at the present time cuts across thick beds of glacial drift *in situ*, showing clearly that this stream has adopted its present course since the glacial period, or, at the earliest, at some late interglacial time. Since the diastrophic movement referred to took place before Pleistocene times, probably during the late Cretaceous or Pliocene

[13] For location of wells see accompanying topographic map.

period, the fact above mentioned disproves the theory that diastrophism caused the diversion of this stream. In further proof of the theory that Moot's Run has taken its present course since glacial times, is the fact that in none of the rock gorges in question do we find any glacial drift *in situ*, either in the bed of the stream or on the side of the valley, a condition which would not be likely to exist if the glacier had moved over this area since the gorges were formed. We find glacial drift on the top of these walls, but none within them.

Since we have seen that neither the diastrophic theory nor that of piracy will account for the drainage diversions in Moot's Run, we must turn to the only remaining alternative, the glacial theory.

Glaciation as an adequate cause. The glacial theory seems to account for the reversal in a very satisfactory manner. Before taking up the relation of the glaciers to the topography of this area, we will give a more detailed description of the region.

If one should start to ascend Moot's Run from its confluence with the Raccoon, he would find that for the first mile it is superimposed upon a mantle of glacial drift, which gas wells show to be about 200 feet thick. At the end of this mile, where is found the iron bridge on the Granville Road three-fourths of a mile east of Scott's Corners, the valley on both sides of the stream bed takes on a different appearance. About 75 yards to the south of the Granville Road the first outcrop of rock appears on the east bank of Moot's Run. The west bank for a long distance is a heavy band of drift, a portion of a recessional moraine that sweeps away to the north; the significance of this ice-halt, in the present problem, will be made apparent later. The rock on the east bank also soon gives place to drift, which forms the east bank of the stream for over half a mile southward. The drift on the west bank continues to Parry's, with the exception of two thin outcrops of rock, which are merely an extension of the rock slope from the opposite side rather than a distinct rock wall.

From beneath the drift at Parry's there emerges a sloping rock wall of rather steep gradient. On the east bank the rock appears a little farther down stream than it does on the west; from this point to the bend, 100 yards south of Parry's and for another 100 yards to the west of the bend, the stream is confined by a rock channel. Here the south rock wall ends, and, together with the

drift on its slopes, forms a commodious amphitheater, which is somewhat dissected by a large tributary, which joins Moot's Run, from the southwest. The rock on the north bank of the stream drops almost to the water's edge, giving place to drift *in situ*, with a very distinct contact. This drift wall flares to the north, its surface rising gradually in the same direction, but not reaching a level as high as that of the stream wall on the south.

The first tributary, south of Parry's, enters Moot's Run by cutting across a portion of the rock wall on the south side of the stream. For over 50 yards up this tributary rock walls confine it; at the upper end, these walls are about 160 feet apart. The wall on the west side is much lower than that on the east, making the tributary appear to enter Moot's Run on the side rather than at the axis of the valley; this lower rock wall, heavily overlaid with drift, blends into the drift deposits, rising to the south, which form the south side of Moot's Run Valley.

As one proceeds up this stream, which has many small tributaries, he finds glacial drift *in situ;* how thick this drift is we cannot say, in the absence of well records, but as there is drift in the bed of the stream at levels lower than the rock at the "bend" in Moot's Run, a preglacial valley is strongly suggested. The direction of flow of this preglacial stream was probably to the northwest, joining the Raccoon Valley; this inference is based on the following facts: The rock outcrop mentioned above, in the first tributary, the shoulder of rock in the opposite bank a little farther down stream, and the last outcrop in the north bank of Moot's Run, about 100 yards west of the "bend," where rock gives place to glacial drift, are in line; these outcrops probably represent portions of the northeast valley wall of this northwest flowing stream. The valley of Moot's Run, west of the last outcrop of rock, is cut for some distance in glacial drift, showing that here it crosses a buried valley.

The second tributary, near its junction with Moot's Run, has a north-south course for about one-fourth of a mile; at the point where it bears to the west "blue clay"[14] appears, showing that the old channel, just referred to, bends slightly to the west before turning northward to the Raccoon Valley. Proceeding upstream

[14] *Journal of Geol.*, vol. xvii, 1909, pp. 473–487. "Metamorphism of Glacial Deposits," F. Carney.

along the second tributary, we find that it cuts directly across the southwest wall of the preglacial valley, exposing rock almost to the top of the channel. Rock walls, for the most part, confine this tributary throughout its course to a point a short distance west of the highway north of the Lewis School, then suddenly give place on both sides to glacial drift. Here we have a repetition of the same phenomenon observed at Moot's Run, i.e., a narrow rock gorge succeeding a wide valley confined between walls of glacial drift. This stream in its westward portion lies on the "blue clay," which may represent an older ice invasion than the yellow drift composing the terraces above. This relationship suggests another buried channel.

Returning to Moot's Run, and tracing its course westward from the point where the rock bed gives place to drift, a short distance west of the "bend," we find that both walls are composed chiefly of drift for almost all the way; the valley walls are fairly high, and have the gentle slope which drift always takes. There is an occasional outcrop of rock in the bed of the stream, one in particular being noted near the house of T. Carroll, where the rock is at least 50 feet higher than at Parker's. This is probably due to the fact that the last records are from wells sunk into the descending rock slope of the old channel, which cut tangentially across the headwaters of the second tributary a little to the southeast of this point.

Résumé of glacial movements over the area. The first glacial invasion of this region, according to present knowledge, was the Illinoian, which probably reached as far south as Cincinnati, Ohio. At its farthest extent the ice front lay across Licking County in a northeast and southwest direction; we infer this from the fact that the southeast portion of the county is driftless. A very large portion of Licking County is the modified topography of a terminal moraine. The Illinoian drift is probably represented by the old "blue clay," a metamorphosed glacial deposit,[15] and the Wisconsin is represented by the so-called "yellow clay."

These ice sheets, making their final stand, deposited very heavy blankets of drift, which masked the minor drainage lines of this area. Observations on the thickness of this drift in the Alexandrian area are given by Scheffel in the paper cited above. It is probable that in our area the heavy drift deposits of the ter-

[15] Carney, *loc cit.*

minal moraines obliterated nearly all the minor drainage channels, leaving little besides the very general divide lines.

In the retreat of these ice sheets, the ice departed from the low areas last. Thus we have at each retreat of the Illinoian and Wisconsin sheets a large lobe of ice protruding down the Scioto Valley. From this lobe there extended eastward a tongue of ice which followed very closely the topography of the Raccoon Valley.[16]

Influence of glacial invasion on subsequent drainage of area. We can now see the influence that this tongue of ice exerted in shaping the drainage features which form the present topography of the Moot's Run area. The topographic map (Granville quadrangle) shows that Moot's Run lies on the side of the slope of its divide and not at the base of it; this divide, which is roughly parallel to Moot's Run, has a northwest-southeast direction. At one time it probably formed the rock wall of the old Raccoon. The outcrops of rock in the Moot's Run gorge represent the northern limit of this rock slope. From a study of the outcrops along Moot's Run and its tributaries, we have outlined the most likely extension of this wall through the area.

What would be the effect on drainage lines, if a tongue of ice from the Scioto lobe halted for some time against this divide? That such a halt did take place, we are convinced from a study of the extensive moraine deposits on the west side of the Moot's Run gorge. We also infer that in this area the tongue of ice conformed very closely to the topography of the region. Mather[17] and Scheffel[18] speak of a similar conformity in the adjoining areas. When the ice stood in the Moot's Run area, in the position above described, the axis of the divide inclining toward the ice, the drainage which flowed normally from this incline toward the Raccoon Valley would be blocked, and as a result would have to take a course along the ice front. This volume of water, augmented by the enormous amount supplied by the melting ice, and employing as tools the drift from the ice, would easily cut through the rock walls, which are of a very soft texture, mostly shale. The places where it cut across the foothills of the old

[16] Scheffel, "The Origin of Spring Valley Gorge," *Bull. Sci. Lab., Denison Univ.*, vol. xiii, 1907, pp. 154–166.

[17] Mather, *Bull. Sci. Lab., Denison Univ.*, vol. xiv, 1909, p. 176.

[18] Scheffel, *loc. cit.*, p. 164.

divide are now the rock gorges in the second tributary and in Moot's Run.

The peculiar phenomenon that we observed in the amphitheater where the second tributary joins Moot's Run is explained as follows: The collar of drift which now extends across the east side of the amphitheater is the remains of a much heavier recessional moraine, representing the position of the ice and the course of the second tributary when it made its first cut through the rock divide. But, as the ice began to retreat, the first and second tributaries took different courses, the first tributary keeping to the old course and the second tributary cutting in on the near side of the rock, keeping always against the ice front.

What is known as Moot's Run on the map did not exist when the gorges were cut. This stream has been formed for the most part since the glacier left the region. The glacier may, however, have given it the initial impulse, by a short halt of the ice where the road is now, as there is good evidence of a recessional moraine along the Granville Road, bearing to the north of Scott's Corners. It is safe to infer that this part of the stream has been cut by normal erosion in fairly recent times. If this were not the case, there would not be so many steep cliffs, which characterize young streams. This can easily be explained through the agency of normal erosion, as the second tributary into which this stream flowed was reduced to such a comparatively low gradient by the heavy ice marginal drainage.

There remains one point for which we need to account: the fact that at the bridge spanning the second tributary north of the Lewis School, the north bank is composed entirely of drift. The most plausible interpretation for this is the supposition that the ice front formed the north wall of the stream until it had cut down far enough to retain its present channel after the ice had receded from the area.

We believe we have shown that neither diastrophism, taking the form of a limited differential tilt, nor piracy, can possibly be considered as even a partial explanation of the drainage diversion in this area. In view of the fact that the only remaining alternative, glaciation, does account in a thoroughly consistent manner for all the peculiar relations that we have noted, the conclusions of the following summary appear justified.

Summary

1. Piracy is not competent to account for these changes, because the present stream drainage is not sufficient to have cut the gorges found in the area, and because the streams are superimposed upon glacial drift for a large part of their courses.

2. Diastrophism is not competent to account for these changes, because at the present time the rock floor dips to the west, precluding the possibility of a differential tilt diverting to the east the normal drainage of the area.

3. These drainage reversals are of Pleistocene age, because of the fact that the supposed diastrophic movement took place in the late Cretaceous or Pliocene period.

4. The distribution of moraine shows that a tongue of ice halted in the Moot's Run area and diverted the drainage, causing it to take a course along the ice margin. This drainage cut the second tributary and Moot's Run below their junction at the rock gorge.

5. Evidence also shows that the so-called Moot's Run in its upper course was nothing more than a tributary to its second main auxiliary, but has cut through a less resistant material, glacial drift, and has eroded its bed much faster, thus becoming the main stream.

6. The present drainage of the Moot's Run area has been superimposed upon a heavy recessional moraine, largely independent of preglacial drainage lines.

SOME PRO-GLACIAL LAKE SHORELINES OF THE BELLEVUE QUADRANGLE, OHIO[1]

FRANK CARNEY

INTRODUCTION

Observations and studies of others. The area comprised in the Bellevue quadrangle includes portions of Sandusky, Erie, and Huron Counties. N. H. Winchell, in his *Report on the Geology of Sandusky County*,[2] merely refers to "the Lacustrine sand," which caps the limestone ridges, as "the only observable changes of level." In the *Report on the Geology of Erie County and the Islands*, J. S. Newberry only mentions "the lake ridges which traverse the county from east to west" as among "the most interesting features in the surface geology of Erie County."[3] *Report on the Geology of Huron County*, by M. C. Read,[4] contains several interesting allusions to the work done by the ice-front lakes. He noted "the old water plains, diversified by sand dunes and remains of old lake beaches;" he noted that the sand hills and associated ridges have the same elevation above lake level; that "the irregular, winding outline" of the ridges and the bordering dunes resemble the results being produced today by waves;

[1] Published with the permission of the Ohio Geological Survey, the author assuming responsibility for the observations and conclusions stated.

[2] *Geological Survey of Ohio*, vol. I, p. 594, 1873.

[3] *Ibid.*, vol. II, p. 183, 1874.

[4] *Ibid.*, vol. III, pp. 290–309.

that there is a difference in height of the north and south slopes of the ridges; and he also observed, near the county line (this is northeast of Strongs Ridge) "a low rock bluff," associated with a sand ridge, which he interpreted as the shore of a lake.

But the first, and only detailed study of any shorelines of the Bellevue quadrangle, so far as the writer is aware, is that of Mr. Frank Leverett, whose "Map of Beaches near Sandusky, Ohio,"[5] includes the eastern half of the Bellevue sheet and a large part of the Sandusky sheet which is next east. These quadrangles were not issued when Mr. Leverett did his work, and he had to depend chiefly on railroad levels for his altitudes. His map shows the Maumee, Belmore (Whittlesey), and Forest (Warren) beaches, two islands of the Warren stage, and a "Maumee bar" on one of these islands, i.e., on Sand Hill; the text refers also to one more island, about three miles directly north of Bellevue on the Sandusky-Erie County line. The small scale of Mr. Leverett's map precludes much detail. In only one particular of much importance is later investigation at variance with this map: Northwest of North Monroeville the Belmore beach crosses the county line, and is represented as turning south and west, again crossing the county line, and terminating about three miles northeast of Bellevue. On Fig. 1, of the present paper, it is noted that a spit of the Lower Maumee, northeast of Strongs Ridge, ends very near the Whittlesey (Belmore) beach; viewed from the highway, this spit might easily be taken as a continuation of the Belmore beach.

Surface features of the quadrangle. This area is underlain by rocks of the Upper Silurian and Middle Devonian; the former are basal to the more even-surfaced northwest part of the quadrangle. The plain of Lake Warren bears many slight streams draining into Sandusky Bay. Considering the sheet as a whole, there is a conspicuous absence of streams, even when allowance is made for the general flatness of the area; this is accounted for by the fact that the higher parts have underground drainage through the cavernous limestone. Sink holes are numerous in the central portion of the quadrangle from Bellevue to Castalia. The sub-surface water courses are used, unwisely, for sewage

[5] *Monograph XLI,* U. S. Geol. Survey, plate XXII, 1902, pp. 730–731, 752, 763.

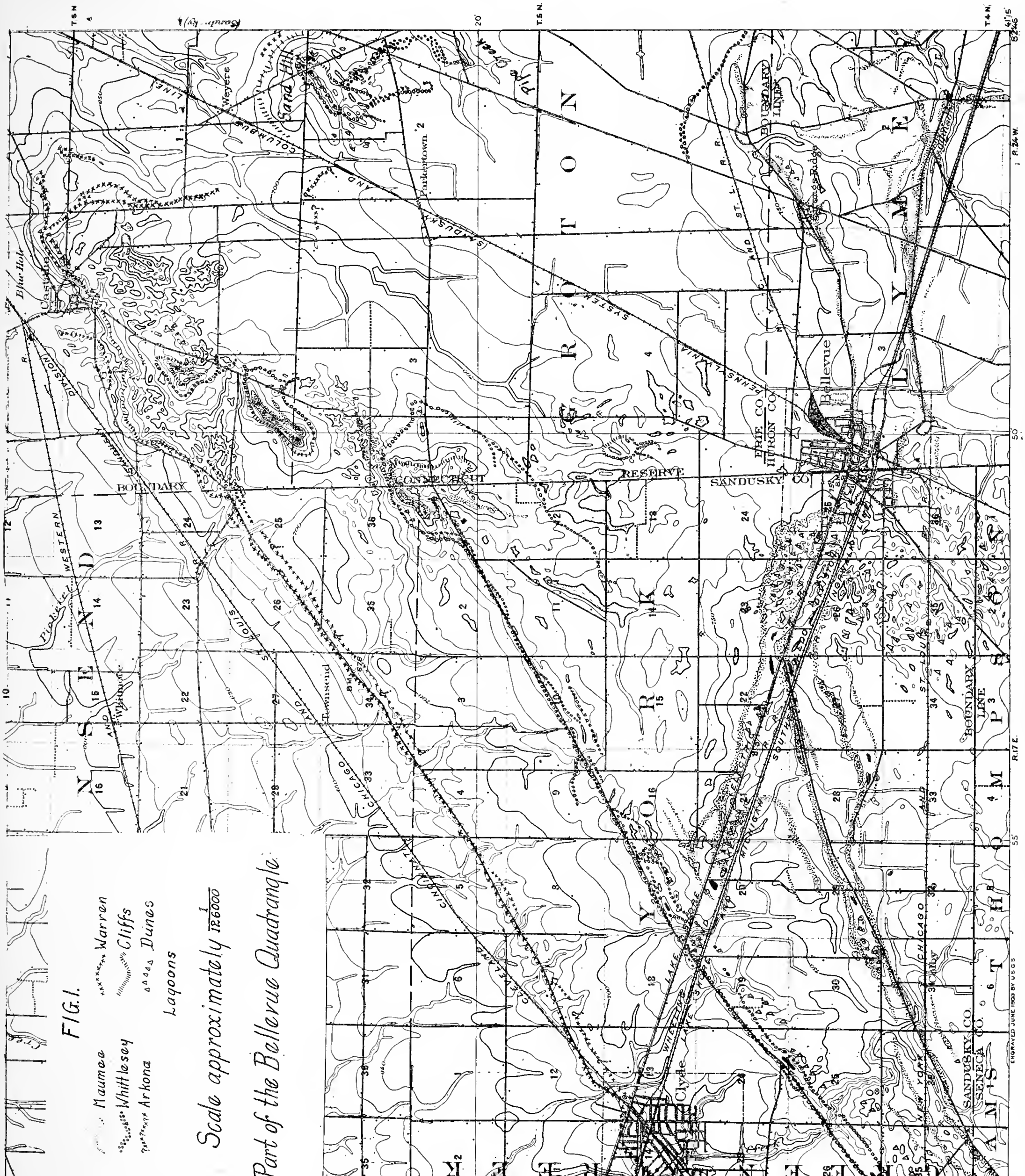


FIG. I.
Maumee
Whittlesey
Arkona
Warren
Cliffs
Dunes
Lagoons
Scale approximately 1/126000
Part of the Bellevue Quadrangle

disposal; and the farmers find them convenient in disposing of excess water from their fields. The "Blue Hole" near Castalia is the outlet of an underground stream.

Near the south side of the sheet several limited areas rise slightly above the 790-foot contour, and a few dunes reach 800 feet. The more important relief features of the area are due to outcrops of limestone; the shoreline structures and dunes are of minor importance; however, the altitude of some of the hills has been increased 25 feet by dunes blown up from the fringing beaches. The series of hills have a general northeast-southwest direction in alignment with the axis of the Cincinnati anticline which here, as elsewhere in the state, is frequently a drainage divide.

Résumé of lake history. Many workers in geology have contributed to our present knowledge of the pro-glacial lakes. In the Erie basin, which alone is concerned in the present paper, the most recent and critical work is that of Mr. F. B. Taylor and Mr. Frank Leverett. My indebtedness to these gentlemen can not, in all cases, be specifically cited, because in conversation and by correspondence they have given me the benefit of findings as yet unpublished.

It was formerly thought that the recessional movement of the ice-front, during the Wisconsin stage, was interrupted only by halts which are indicated today by the morainic loops about the lake basins. Later it was established that slight oscillations of the ice-margin varied the regressive movement. At least one such readvance was registered on the Thumb of Michigan[6] (the peninsula between Saginaw Bay and Lake Huron); theoretically there must have been two other advances of the ice in this area, though the evidence has not been published.

In reference to the history of several of the pro-glacial lakes of the Erie-Huron Basin, the Thumb of Michigan was a critical area, because, flowing westward across it, lay the outlet channels of these lakes; a readvance of the glacier might cover a given channel, and bury part of the correlating beach beneath outwash deposits; Taylor reports this condition.[7]

[6] F. B. Taylor, "Relations of Lake Whittlesey to the Arkona Beaches," *Mich. Acad. of Science*, report for 1905, p. 34.

[7] *Ibid.*, p. 34.

In the table given below, the lake stages are named in chronological order; but their shorelines do not have a corresponding altitudinal sequence, for the reason that a readvance of the glacier covered the overflow channel last in use, and forced the water to seek a higher outlet, the lake becoming deeper and submerging the shoreline formed when the buried overflow channel was in use. The drowned beach would be altered: if not covered by a great depth of water, the waves and currents would make it "faint and fragmentary;"[8] in any event, the beach would be made "stiffer and more firm than ordinary beach soil . . . . by the infiltration of clay."[9]

LAKE STAGES IN CHRONOLOGICAL ORDER	LOCATION OF OUTLET	ALTITUDE OF SHORELINE IN NORTHERN OHIO
		feet
Highest Maumee, "first" beach	Fort Wayne, Ind	790±
Lower Maumee, "third" beach (submerged)[10]	Presumably across the Thumb of Michigan	760
Upper Maumee "second" beach	Fort Wayne, Ind.; Imlay, Mich.	780
Arkona (submerged)[11]	Grand River, Michigan	700±
Whittlesey[12]	Ubley, Mich.	735
Wayne (submerged)[13]	Near Syracuse, N. Y	660
Warren[14]	Grand River, Mich	680
Grassmere[15]	Near Syracuse, N. Y	640
Elkton[16]	Near Syracuse, N. Y	620

[8] *Ibid.*, p. 33.

[9] *Ibid.*, p. 33.

[10] Mr. Leverett first called my attention to this interpretation of the "third" Maumee beach.

[11] Mr. Taylor first called attention to the Arkona as a submerged beach, and showed its time relation to the Whittlesey lake; *loc. cit.*

[12] F. B. Taylor, *Bull. Geol. Soc. America*, vol. VIII, p. 39, proposed this name.

[13] This was formerly called the Lower Warren beach. Mr. Taylor finds it to be older than Lake Warren, by which it was submerged; his interpretation of this episode in pro-glacial lake history will appear shortly in *Monograph No.—*, "The Pleistocene Deposits and Glacial Lakes of Indiana and Michigan," by Leverett and Taylor, U. S. Geol. Survey, part II, chapter XVIII.

[14] The present restriction in the use of the term Warren was proposed by Taylor, *Bull. Geol. Soc. America*, vol. VIII, pp. 56–57, 1897.

[15] This designation was proposed by Mr. A. C. Lane, *Ann. Rept. Geol. Surv. of Michigan*, 1907, p. 131.

[16] Also proposed by Mr. Lane, *ibid.*, p. 132.

The shorelines of only three of these lake stages have been given detailed study on the Bellevue quadrangle. When the field work herein described was undertaken, about four years ago, the writer was not acquainted with any beaches, in northern Ohio, below the Warren; these lower beaches are nowhere suggested by the contours of the Bellevue sheet; in recent summers, however, he has found evidence of these lower beaches on sheets farther west, and he anticipates mapping them later on this quadrangle. There remains also some further work to be done on the Arkona, the significance of which was not fully appreciated in the season of 1909.

Lake Maumee Shorelines

The Upper Maumee shoreline. Commencing on the eastern side of the sheet, the Upper Maumee beach is found along the first north-south highway near the southeast corner. Megginson Creek, the course of which has been influenced by the direction of the beach, cuts through this shore ridge just south of its turn to the west. Within the next mile and a half westward there are some interesting irregularities in this shoreline, in consequence of the influence of west winds. The details can be better understood by starting at a point directly south of Bellevue, where the highway turns northward along the shore of a small pond in section 3 of Lyme Tp. Here the beach has a mild development, but as we follow it to the east by the road, the ridge swinging back and forth across the highway, it grows stouter, and after crossing the Lake Shore Railway the beach shows a strong development. A cusp extends northward about a quarter of a mile along the highway to Strongs Ridge. The road eastward from this cusp follows the crest of the beach for a little more than a mile to a point where the ridge bears north from the highway; a short distance east, the ridge swings back across the road and proceeds southward as already described.

Returning to the cusp on the Strongs Ridge road, we find a spit which grew eastward, developing a northward trend for a short distance and later veering to the south in accord with the depth of the water. About half of a mile east of the western end of this spit, and south of it, a barrier commenced to form and grew eastward for nearly a mile, where both the spit and the

barrier are tied to an area of gravel and sand which bears a cusp-like relationship to the original shoreline. Extending eastward from this cusp-like protuberance is another spit about one-half mile long. A further detail is seen in a ridge of sand, which parallels the two spits just described, and is attached at its eastern end, but I was unable to find that it has any connection with the shoreline proper at its western end; this ridge may have originated as an off-shore barrier and, as the upper level receded, the deposition work of along-shore currents tied it at only one end.

Returning to the meridian of Bellevue, we see on the map isolated gravel patches south and west of the village, as well as an extensive area of dune sand to the southwest. Apparently nearly all of the southern end of the quadrangle, west of Bellevue, was under water during the early part of this Maumee stage. I have been unable, however, to find sufficient sand or gravel in the ridge form to warrant mapping the beach south of the ridge segments indicated. The extension of wind-drifted sand so far south, particularly when we assume that the prevailing wind came more directly from the west, is the reason for hypothecating a former greater extension of Maumee waters in this locality.

For the first mile and a half west of Bellevue, the area included between the Lake Shore Electric, and the Wheeling and Lake Erie Railways, is so continuously covered by sand and gravel that any mapping of the Upper Maumee level must be largely guess work. One can only say that the shoreline crossed this area, and that in post-glacial time there has been so much shifting of sand that the beach itself is obliterated.

Near the point where the Lake Erie and Wheeling Company has a spur, north of its track, leading to a gravel pit, the Upper Maumee beach becomes sufficiently distinct for study. Westward from this point it continues as a ridge, four to ten rods in width, consisting largely of gravel but on its surface becoming progressively more sandy. The several mounds which just reach the 800-foot contour line indicate dunes along this beach ridge. Paralleling this ridge and about a quarter of a mile south is a slighter beach marking an earlier temporary position of the shoreline; how much this differs in altitude, if at all, from the former can not be established, because of wind deposits; it may be the

original position of the shoreline, later isolated by a barrier becoming a beach. The two ridges coalesce one-half mile west of the next north-south highway, and for the next mile and a half the Upper Maumee level is marked by a strongly developed beach. Just west of Colby Station on the Nickle Plate Railroad is found a ridge about three-quarters of a mile long, apparently correlating with the higher ridge above mentioned. The Upper Maumee level proper is indicated by the highway which extends to the southwest, and leaves the sheet about one-half mile east of the western border. Several sand dunes are found in the last mile of this beach.

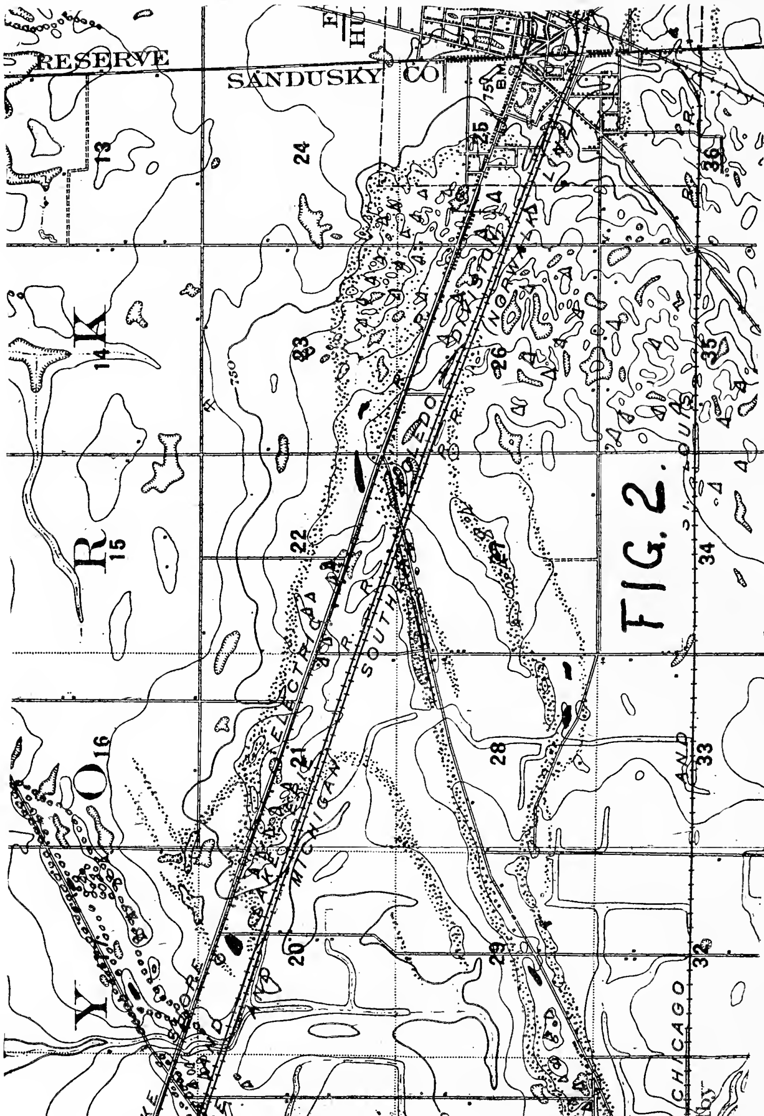
Islands. The arch of limestone which accounts for Kelley's, Johnson's, and other islands in Lake Erie, made several islands in the pro-glacial lakes. Only the southernmost of the three islands shown on the map, near the Bellevue-Castalia highway, figured in the Upper Maumee stage. This island was very small and may have consisted chiefly of a shoal area. Along only its northwest side is there a beach ridge; the north end of this ridge has a back slope 12 feet in maximum height; the continuity of the ridge and the absence of sand protuberances on its leeward side appear to preclude interpreting it as a wind deposit, although the surface shows sand fine in texture. The general sandy condition of the island's top may be interpreted as wave work of the Upper Maumee; but the same surface condition could be due to later wind-drifting of sand.

The Lower Maumee shoreline. Near the eastern side of the Bellevue sheet, the shoreline of the Lower Maumee level consists of disconnected ridges of sand and gravel. The poor initial development of the shoreline here is due to the fact that limestone, outcropping in the vicinity of Strongs Ridge, acted as a protection against wave-work, and also as a source of abundant sand which formed a spit extending northeastward for over a mile. Near the eastern end of this spit there are two hooks which were later isolated by the spit growing farther into the bay. Leeward of this spit was quieter water, hence a mild beach. This irregular spit owes its location to the shallow water caused by the extension of the limestone outcrop. Furthermore, this spit, even in the absence of shallow water, is normal, as it represents the tendency of the shoreline to straighten itself into the Huron River embayment.

The highway from Strongs Ridge to Bellevue follows the Lower Maumee beach. In the vicinity of Bellevue the shoreline bears southward; the Bellevue cemetery occupies a locally broadened portion of the beach. Its location immediately west of this is somewhat problematical, owing to street grading and building operations. Within half a mile west of the village the Lower Maumee shoreline bears northward, and becomes much broader than elsewhere on the quadrangle. The last position of this lake stage, in this vicinity, may be quite definitely mapped; earlier positions of the beach ridge farther south are indicated by gravel pits operated at present by the Wheeling and Lake Erie Railroad, about a mile west of the Bellevue Cement Company's plant. At this gravel pit the upper 4 to 5 feet consists of wind-drifted sand, beneath which is found some very coarse wave-made gravel. In an area nearly a mile square here the surface material is all wind-deposited.

Proceeding west, the beach of the Lower Maumee level parallels a highway that turns diagonally south and west from the road followed by the Lake Shore Electric. From this point to the southwest corner of the sheet the ridges of the two Maumee levels are approximately parallel. At a point about a half mile northeast of Colby they have been united by wind deposits. For nearly two miles west of this, the lower beach lies a little farther away from the higher ridge, but near the edge of the sheet the two are less than 40 rods apart. In this corner of the quadrangle I have mapped what appears to be a low off-shore barrier, the material of which is prevailingly fine; locally its surface is somewhat irregular because of dune deposits; the barrier characteristic is the continuity of the broad swell of sand.

From the point where the Lower Maumee ridge turns to the southwest from the Lake Shore Electric, there developed to the west one of the most interesting spit formations I have noted anywhere in these studies. From its point of origin in section 22 of York Tp. this spit extends westward over two and one-half miles. The map (Fig. 2) attempts to show as much detail as is possible after eliminating the work of wind deposits; I have allowed only gravel and ridged sand to define definitely this structure. It is observed at once by those who are familiar with the shoreline of Lake Erie, that a striking similarity exists between this spit (Fig. 2) and the Cedar Point spit (Fig. 3). Both have the


RESERVE
SANDUSKY CO
FIG. 2.

same orientation, and are identical in some other details, such as a secondary spit on the inner side, and another on the north shore side; extending eastward from this latter detail of the Bellevue spit, I have mapped three slender ridges of fine sand subaqueous in origin; similar subaqueous ridges are forming eastward from the Cedar Point spit. The secondary development on the south side of the Bellevue spit appears to have grown shoreward till it united with an off-shore barrier in section 21 of York Tp.;

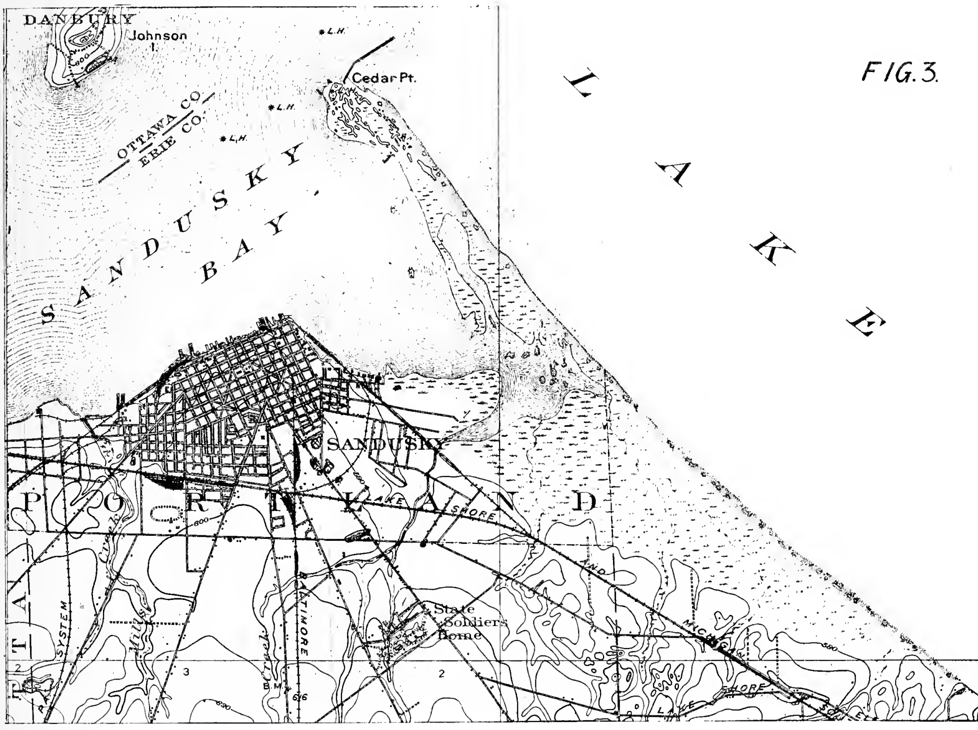


FIG. 3.

an analogous formation appears to be under way at present in Sandusky Bay. The extensive areas of black muck soil in the southeastern part of section 21 and in adjacent parts of other sections of York Tp. indicate that for some time this off-shore barrier and the spit with which it had been united marked the shoreline itself.

When compared with other sheets in Ohio, the Bellevue quadrangle shows the Lower Maumee shoreline in a remarkably well

preserved condition. This must be accounted for largely by assuming a stronger initial form due to an ample supply of detritus for beach-building. However, the characteristic features of a submerged beach are easily detected.

Islands. During the Lower Maumee level, the northernmost of the three islands southwest of Castalia was the smallest in area; its northern shore was cut into a cliff; a beach of gravel and sand forms the remainder of its shoreline; two spits, each about 60 rods long, trend southeastward from the south side of the island.

The middle island does not show any definite cliff. Active wave work, however, is indicated by an abundance of detritus, derived probably from the limestone which was planed to the level of effective wave erosion, and covered. The whole surface is now sandy; in places the sand is in mounds. From near the south end a ridge of sand extends about 70 rods to the northeast, growing finer in texture toward the terminus.

At the close of the Lower Maumee stage the southernmost of these islands had an area of approximately one-half square mile. Steep rock slopes form two-thirds of the island's shoreline. A ridge one mile long extends southward from the middle of the west side; throughout the first half-mile the ridge consists of coarse gravel; it becomes finer in texture southward.

Lake Whittlesey

In the eastern part of the Bellevue sheet the Whittlesey shoreline is not continuous nor are the beach segments well developed, a condition due to the very gradual deepening of the water, and to the windward location of a headland. Throughout the first one and one-half miles the ridge is easily traced; thence for nearly five miles I was unable to give it a definite mapping, though a broad stretch of sandy soil is evidence of wave work. Just east of the Sandusky County line an area of limestone formed an island; on its northern and eastern sides a cliff was cut; elsewhere about the island gravels accumulated; from its southern end a strong spit grew southward nearly one-half mile, terminating in a hook to the west; another slighter spit, a short distance west of this, also developed southward.

At a point about one and one-quarter miles west of this lime-

stone island, commencing in section 14 of York Tp., the beach ridge proper of the Whittlesey level is again found; a school house on the north side of the highway stands near the beginning of this beach. For nearly three miles directly northeast, a ridge of sandy clay marks the work of Whittlesey waves; thence the shoreline turns to the northwest, and becomes quite irregular because of limestone islands, a condition that makes mapping of the shoreline rather problematical. I have indicated some isolated patches of what appear to be wave-worked materials, extending eastward from a cliff phase of limestone. After crossing the Sandusky County line again this beach bears southward for approximately one mile, thence southwest for nine miles, being traversed by a highway continuously to the western border of the quadrangle. As indicated on the map, there are several segments or ridges varying in length, south of the main ridge, which mark earlier, but more temporary positions of the Whittlesey shoreline. Within about a mile of the Lake Shore Electric Railway the ridges become more complex both genetically and by later drifting of sand. South of the Lake Shore and Michigan Central Railroad an inner ridge has been mapped which is continuous, except where cut by streams, to the edge of the sheet.

Islands. An island northeast of Parkertown is locally known as Sand Hill; it was about one mile long, and did not stand very far above the Whittlesey level. The limestone of which it is composed furnished the waves a supply of material for erosion and transportation; cliffs border the northern and northeastern sides of the island. Along its west side are beach deposits, the finer surface parts of which have been drifted inland by the wind; the topographic map appears to indicate several of these dunes, the axes of which, however, are erroneously given a northeast-southwest trend; their direction is more nearly east-west. From the southwestern part of this island a short spit was built into the deeper water. About 40 rods east of this, a strongly developed spit, composed entirely of limestone gravel which becomes finer in texture toward the terminus, extends southward for over one-half mile; this spit has a recurved termination which is very typical in all its measurements; Fig. 4 gives a longitudinal profile and the ground plan of this hook-termination; the direction of the curve shows clearly the influence of deeper water south of the island, carrying the predominating waves to the east.

Joined to the eastern side of this island is another spit of prevailingly coarse limestone material, about one and one-half miles long. Throughout the first three-quarters of a mile, this ridge shows the influence of currents from the north; as the spit neared the axis of the depression now drained by Pipe Creek, the water being deeper gave the waves impelled by the winds from the east a fuller sweep, which tended to turn the spit westward; near the angle, I have mapped three distinct ridges indicating a succession of new spits starting from the angle. The spit continued westward for about one-quarter mile; at that point

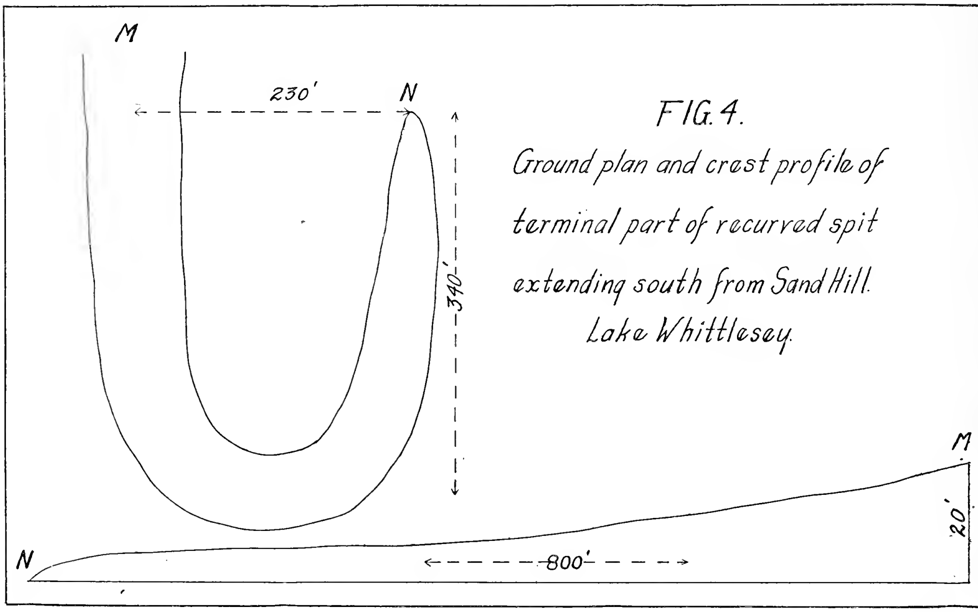


FIG. 4. Ground plan and crest profile of terminal part of recurved spit extending south from Sand Hill. Lake Whittlesey.

the influence of winds from the west caused it to take a more southerly course. The spit ends a few rods south of the highway; its last half-mile is very much finer in texture than the part developed earlier.

The highway from Castalia to Bellevue crosses two other islands of the Whittlesey stage. The southern of these, on its eastern side, has a well developed beach ridge in which limestone cobble and gravel prevail; on the western side is a cliff with scant gravel and sand at its base. The northern of these two islands is characterized on its west and northwest sides by a beach ridge; at

its southern end, by two spits bearing to the east, both of which are crossed by the above mentioned highway; north of these spits for a distance of about one-quarter mile the shoreline is not distinctly recognizable; a cliff marks the remainder of the island's periphery.

Lake Arkona

The mapping of the Arkona on this sheet is not final; it is known to be incomplete, and there is uncertainty as to some of the deposits interpreted as Arkona.

A submerged beach loses some of its sharpness even when initially strong. The ridge suffers from the work of waves and currents unless covered by a considerable depth of water; in case the transition to the higher stage was effected slowly, there was greater modification of the shoreline. However, the local discontinuance of a beach does not always mean modification; a beach may never have been formed in that place. Along the lakes of today, there are stretches where no shoreline features are developing.

West of Sand Hill there are two low segments of sandy beach slightly above the 700-foot contour. Near the Castalia-Clyde highway, and parallel to the Warren shoreline, are many strips of beach, in places above the 690-foot contour and elsewhere a little below that altitude according to the topographic sketching, which probably represent the Arkona. Another segment is mapped southwest of Clyde; wind deposits in this locality have rendered the mapping quite indefinite.

Lake Warren

The Warren level, throughout the first mile commencing on the eastern side of the Bellevue sheet, is indicated by a cliff skirting Sand Hill. Lying off-shore, near the margin of the quadrangle and continuous with a ridge on the Sandusky sheet, is a low swell of sand, a barrier beach. The cliff slope in the limestone disappears near the Pennsylvania Railroad, west of which is an interval of nearly a mile in which I am unable to find any trace of a shoreline. Eight-tenths of a mile directly west of Weyers is a sandy area which blends northward into a well developed shore ridge, increasing in height toward Castalia. The

outcropping limestone about Castalia furnished an abundant supply of detritus which was drifted alongshore to the south; the terminal part of this ridge bore a spit-relationship to the bay-like expansion of shallow water west of Sand Hill. As indicated on the map, this shore ridge is composite for one-half mile; near the southern junction of the two ridges the Pennsylvania Railroad, several years ago, operated a gravel pit.

Along the east-west highway, directly east of the point where the above mentioned shore ridge commences to bear to the west, a small outlier of limestone formed either an island or an area of very shallow water, southward from which a spit developed; gravel and sand now mark the island or shoal area.

From the angle in the shoreline, just east of Castalia, a spit of large proportions was built eastward one-half mile; its boundaries are somewhat irregular now because of wind deposits. The rather steep limestone slope from this angle westward for approximately one mile bears near its top a ridge of sand and gravel which marks the Warren stage; a period of active wave erosion was followed here by one of beach construction. This ridge extends to the southwest as far as the highway which leads from Castalia to Bellevue. After crossing this highway, the shoreline becomes a cliff in the limestone, and so continues to the more southerly turn of the Clyde highway; the terrace is sandy. In the vicinity of Castalia wind-drifted sand fringes the inland side of the beach.

The Clyde highway follows the Warren beach to that village. Fine gravel and sand prevail; in places the sand has been drifted into mounds. The water side of the beach has a gentle slope; occasionally a steeper slope marks a locality of more active wave erosion. The back slope is regularly short and often steep; its initial curve has been modified by weathering and by wind deposits; the latter agent has operated particularly in the vicinity of Clyde.

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EDITED BY
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Permanent Secretary Denison Scientific Association

GRANVILLE, OHIO, MARCH, 1914

NOTES ON THE LORRAINE FAUNAS OF NEW YORK AND THE PROVINCE OF QUEBEC

Aug. F. Foerste

1. Lingula clochensis
2. Lingula rectilateralis, Emmons
3. Pholidops subtruncata, Hall
4. Glyptorthis insculpta, Hall
5. Glyptorthis crispata, Emmons
6. Dalmanella centrilineata, Hall
7. Strophomena planumbona var.
8. Rafinesquina nasuta, Conrad
9. Rafinesquina squamula, James
10. Rafinesquina mucronata
11. Catazyga erratica, Hall
12. Caritodens demissa, Conrad
13. Byssonychia radiata, Hall
14. Colpomya pusilla
15. Pholadomorpha pholadiformis, Hall
16. Pholadomorpha pholadiformis—divaricata
17. Pholadomorpha chambliensis
18. Modiolopsis modiolaris, Conrad
19. Modiolopsis concentrica, Hall and Whitfield
20. Modiolopsis postplicata
21. Orthodesma approximatum
22. Orthodesma nasutum, Conrad
23. Orthodesma pulaskiensis
24. Orthodesma prolatum
25. Cymatonota lenior
26. Cymatonota pholadis, Conrad
27. Modiolodon poststriatus
28. Psiloconcha subovalis, Ulrich
29. Psiloconcha sinuata-borealis
30. Cyrtodonta clochensis
31. Ischyrodonta curta, Conrad
32. Whitella securiformis
33. Whitella complanata
34. Whitella goniumbonata
35. Clidophorus planulatus, Conrad
36. Clidophorus praevolutus
37. Ctenodonta lorrainensis
38. Lyrodesma poststriatum, (Emmons) Hall
39. Rhytimya oehana, Ulrich
40. Cuneamya scapha-brevior
41. Archinacella clochensis
42. Archinacella pulaskiensis
43. Lophospira beatrice
44. Ruedemannia abbreviata, Hal
45. Pterotheca cf. attenuata
46. Pterotheca pentagona
47. Cornulites sp.
48. Technophorus quincuncialis
49. Cryptolithus tessellatus, Green
50. Calymene conradi, Emmons
51. Proetus chambliensis
52. Byssonychia carinata, Goldfuss

During the summer of 1912, through the courtesy of the Director, Dr. R. W. Brock, I was given the privilege of carrying on investigations on the Richmond and Lorraine formations of the province of Quebec, under the auspices of the Geological Survey of Canada. These investigations revealed the presence of a great thickness of red clays occupying the stratigraphical position of the Queenstown red clay shales in western New York. These red clay shales were underlaid by fossiliferous strata readily corre-

lated with the Richmond formations of Ohio, Indiana, and Kentucky, and below the latter was a great mass of strata, overlying the black shales which in this part of Canada are correlated with the Utica of New York. This intermediate great mass of strata, between the undoubted Richmond and the supposed Utica, was provisionally correlated with the Lorraine of New York, where, in fact, all of the strata below the Queenstown red clay shales, including the Richmond section, had been placed by the Canadian Geological Survey for a long time.

The known exposures of the so-called Lorraine Formations, in the province of Quebec, were isolated and rather widely scattered, and at first there appeared no prospect of determining their relative position with sufficient accuracy for stratigraphic purposes, but later a very long continuous section was found on the Nicolet River, southwest of Ste. Monique, which made it possible to make at least a beginning on such a line of investigation. At this locality, 157 feet of fossiliferous strata are regarded as undoubtedly Richmond, corresponding approximately to the middle and upper part of the Waynesville member of the Ohio section. The base of this known Richmond section is drawn at the lowest horizon at which *Strophomena planumbona* and *Rhynchotrema perlamellosa* have been found.

Below this lowest *Strophomena planumbona* horizon the section could be followed, along a continuous exposure up the river, for a total thickness, in descending order, of 2352 feet, or 2509 feet below the top of the fossiliferous section underlying the Queenstown red clay shales. This section by no means includes all of the strata down to the so-called Utica black shale, but it served to give clue to the approximate stratigraphic position of many of the isolated Lorraine exposures to be found within the province of Quebec.

It was noted, however, that there were no conspicuous stratigraphic breaks, and that a preliminary study of the fauna, in the field, did not reveal any sudden faunal changes, such as are very serviceable for stratigraphical purposes. It is evident that much detailed investigation is necessary before the full value of this wonderful section for stratigraphic purposes has been worked out.

Among other things, it was found difficult to determine, with confidence, the boundaries between the Richmond and the Lorraine. For instance, specimens belonging to the groups of

Whiteavesia pholadiformis and *Modiolopsis concentrica* occur for a distance of 200 feet below the lowest *Strophomena planumbona* zone on the Nicolet River. These species are common in the lower or Fort Ancient division of the Waynesville member of the Richmond in Ohio, but the similar forms in that part of the Nicolet river section here discussed are not accompanied by the other forms which in Ohio would be expected in the Fort Ancient division of the Waynesville. A similar difficulty was experienced in attempting to draw the boundary between undoubted Richmond strata and those to be assigned to the Lorraine in the section at Streetsville, and at other points farther west in Ontario; also in the numerous Lake Huron sections, for instance that southeast of Meaford, on Workman's Brook, and various sections near Little Current and Gore Bay, on Manitoulin Island.

The difficulty was increased by the fact that a very meager and poorly preserved fauna, submitted to Dr. E. O. Ulrich as coming from the same beds as *Whiteavesia pholadiformis*, in the Meaford and Little Current sections, on Lake Huron, suggested to him Middle Maysville (lower Bellevue) rather than Richmond affinities. Moreover, it is certain that the *Modiolopsis corrugata*, described by Miller and Faber from near the top of the hills back of Cincinnati, Ohio, is a genuine specimen of *Modiolopsis pholadiformis*, and there is every reason to suspect that the *Modiolopsis sulcata*, by the same authors and from the same general locality, belongs to the same species. If these forms were secured from some outlier of the lower or Fort Ancient division of the Maysville, at Cincinnati, this would be their normal position; but if they occurred at some lower horizon, then it might be that forms of the *Whiteavesia pholadiformis* group are not restricted to the Richmond, but occur also at lower horizons.

Under these circumstances it seemed desirable to become familiar with the New York Ordovician section, in order to learn if additional light might be secured from that source. The writer therefore took advantage of an invitation given by Dr. E. O. Ulrich to visit with him the territory east of Lake Ontario, in New York. The Lorraine exposures east of Pulaski, the Oswego sandstone section at the Salmon River Falls, and the fossiliferous sandstone section at the power house at Bennett bridge, a mile west of the Falls, and stratigraphically a short distance below the base of the Falls section were studied under his guidance. Sub-

sequently, various other sections were studied, and a fair reconnaissance of the Lorraine territory made.

One of the results of the investigations at the Bennett bridge locality was the discovery of very typical specimens of *Whiteavesia pholadiformis*, associated with *Ischyrodonta unionoides*, and other forms which Dr. E. O. Ulrich regarded as suggesting middle Maysville (lower Bellevue) affinities. Moreover, at the distinctly lower horizons exposed along the river east of Pulaski, the same *Ischyrodonta unionoides* occurred associated with various other forms which to Dr. Ulrich again suggested middle Maysville rather than Richmond affinities. This is not strange in view of the fact that this fauna at Pulaski contains *Trinucleus*. It is not intended by these observations to convey the impression that the middle Maysville age of the Pulaski and Bennett bridge faunas has been definitely determined, but rather that the Bennett bridge fauna, with its *Whiteavesia pholadiformis*, did not present other forms regarded as characteristic of the Richmond, while forms suggesting middle Maysville age were present there and at Pulaski.

For the present probably it would be safer to assume that the upper or Pulaski part of the Lorraine fauna is younger than the Eden at Cincinnati and older than the upper or McMillan division of the Maysville, while the lower, shaly part of the Lorraine, below the typical Pulaski zone, may be correlated with the Eden. In the absence of fossils, the typical Salmon river falls or Oswego sandstone may be correlated with the upper Maysville.

From the recent studies of Dr. Rudolf Ruedemann[1] it will be seen that the Utica black slate and the overlying dark Frankfort shales were described from the western or Trenton Falls basin of New York. In view of the presence of several basins already discovered it is necessary to remember that the territory west of Rome has not yet been investigated with the exactness demanded for exact correlation. For instance, while Vanuxem regarded the lower, more shaly part of the Lorraine section, in Oswego and Jefferson counties, as equivalent to the Frankfort shales of the Trenton Falls basin, it is by no means certain that the Frankfort shales extend this far west.

[1] The lower Siluric Shales of the Mohawk Valley, *Bulletin 162, New York State Museum*, 1912.

The Pulaski shales were described from the vicinity of Pulaski because here they occur unaccompanied by any other division of rocks. Ascending the stream toward Bennett bridge and the Salmon River Falls, the higher divisions of the Pulaski shales come in, very gradually however, owing to the general westward dip of the strata in this part of the state. Within the limits of the village of Lorraine, horizons are exposed which are regarded as belonging a short distance below those seen at Pulaski, but as still belonging to the Pulaski section. Strata equivalent to the horizons actually exposed at Pulaski come in east of Lorraine, and farther eastward the strata corresponding to the Bennett bridge horizons come in, chiefly however in the drift in the highest hills.

Owing to the westward dip of the strata, the thickness of the Gulf section northwest of Lorraine is less than indicated by vertical measurements above sea level. All of this Gulf section belongs below the level of the actual exposures within the limits of the village of Lorraine. According to Dr. E. O. Ulrich, who visited this section in the company of Dr. Ruedemann, the great mass of strata in the Gulf section shows Eden affinities, and therefore corresponds to the lower part of the Cincinnatian section. It is this part of the Lorraine which Vanuxem correlated with the Frankfort shales of the Trenton Falls basin, but at that time the fauna of the Frankfort shales had not been worked out and Vanuxem's correlation needs confirmation.

Both Dr. Ulrich and Dr. Ruedemann plan to make a more detailed study of the Lorraine in Oswego and Jefferson counties, and their researches will, no doubt, give the definiteness desired. In the meantime it may be observed that the Lorraine exposures of New York show much greater affinities with the much more extended Lorraine sections of the province of Quebec than with any part of the Cincinnatian section of Ohio and neighboring states. Moreover, on proceeding from Jefferson county, in New York, westward along the northern shores of Lake Ontario and northwestward toward Meaford and Manitoulin Island, the Lorraine facies of New York gives way to the Cincinnatian facies of southwestern Ohio, and neighboring states.

The exact significance of these observations is not understood as yet, but apparently the Frontenac axis was sufficiently developed in Lorraine times to prevent a ready access of Lorraine faunas to

the areas northwest of Lake Ontario, while permitting more ready migrations from the province of Quebec.

Nevertheless, there are evidences of the migration of Lorraine faunas even into Ontario. It is probable that the *Whiteavesia pholadiformis* fauna, just beneath the undoubted Richmond faunas, in the vicinity of Streetsville, and farther northwestward in Ontario, was connected with the Bennett bridge fauna, on the upper part of the Salmon River, in Oswego county, New York. Moreover, at the quarries on the Don River, in the eastern part of Toronto, *Trinucleus*, *Catazyga*, and *Leptaena* occur in an association suggesting the lower part of the Nicolet river section, in the province of Quebec, although *Leptaena*, so far, has not been found by me in the Lorraine of New York. *Leptaena tenuistriata* was listed by Walcott from the upper Lorraine fauna, estimated by him to have a vertical distribution of 500 feet beneath the Oswego sandstone, along the south branch of Sandy creek, Jefferson county, New York, but he lists also *Orthis biforata*, and therefore his specimens may, in part, have been erratic. The bryozoans of this Don river section were identified by Dr. R. S. Bassler with Eden and lower Maysville forms.

It is evident that the New York Lorraine section is a much abbreviated representative of the Nicolet river section. No doubt, considerable parts of the Nicolet river section will be found entirely missing in New York. The apparently entire absence of *Proetus* and *Leptaena* in the New York Lorraine, in view of the great vertical range of these fossils in the Nicolet river section, is significant in this direction. In view of these facts there is room for abundant future investigations.

The present paper began with a study of certain faunas, belonging to the Geological Survey of Canada, which had been collected in the vicinity of the Riviere des Hurons and Chambly village, east of Montreal, in the province of Quebec. The material under investigation was increased by collections made by the writer at numerous points in the province of Quebec, under the auspices of the Geological Survey of Canada. In the progress of these investigations it was found desirable to make a special study of the forms described by Hall from the Lorraine of New York. The following pages include a part of the results of these various studies. They differ greatly in value, according to the

familiarity of the writer with the material covered, but it is hoped that nevertheless they may have some value to those interested in these, or corresponding strata elsewhere.

1. **Lingula clochensis,** sp. nov.

(*Plate II, Figs. 11 A, B*)

Pedicel valve 20 mm. long; width 14 mm. along the anterior half of the valve, the sides being parallel here. Posteriorly, toward the beak, the shell narrows, becoming 12 mm. at 7 mm. from the beak, the postero-lateral parts being moderately convex, producing a rather obtuse beak. Anteriorly the lateral margins round rapidly into the moderately convex anterior outline. The anterior outline of the muscular scars reaches 10 mm. from the beak. Only the anterior part is clearly defined. This indicates the presence of a narrow low median septal ridge, less than 1 mm. in width at the anterior end. The total width across the muscular area anteriorly is 7.5 mm. Anteriorly this muscular area is crossed by transverse striae similar to those figured by Hall and Clarke, plate I, vol. viii, *Palaeontology of New York*, in the case of the species identified by them as *Lingula vanhornii* (= *L. modesta*, according to Schuchert), and in *Lingula densa*. Towards the sides these transverse striae are convex toward the front, but curve forward near the median septum. Convexity of the valve fully 2 mm. Notwithstanding this convexity, the median parts of the shell, from the beak to the anterior margin, are somewhat flattened from right to left, the area of flattening widening anteriorly, including nearly the entire width of the muscular area at midlength of the shell, and nearly the entire width of the valve at the anterior margin. Laterally, from the antero-lateral margins almost to the beak, the valve is flattened also, producing a moderately angulate outline in cross-section, the median flattened surface meeting two lateral flattened surfaces at angles of about 20 or 25 degrees. There are indications of concentric striae, and anterior to the muscular area the interior shows fine striae, radiating as though from the beak as a center. It is possible that similar radiating striae were present on the exterior of the shell.

Brachial valve, in the only specimen at hand, having a convexity of fully 2 mm., so that the total depth of the shell from valve to valve equals 4 mm., or one-fifth the length of the shell.

This valve is, of course, shorter than the pedicel valve at the beak, but the amount of shortening in the individual is abnormal, and, no doubt, not a constant feature of the species. The same median and lateral flattening is observed as in the case of the pedicel valve; anteriorly, the median flattened part is radiately striated, on the interior, as though from the beak as a center. The muscular markings are indistinctly preserved. Such outlines as are suggested by the specimen at hand are indicated in the accompanying drawing (Fig. 11 B), and since these do not conform to any structure known among *Lingulae* it is very probable that these outlines are misleading and have no diagnostic value.

Locality. Argillaceous brownish indurated bands, in the red clay shales in the lower Lowville section, on LaCloche peninsula, about a mile south of the contact of these shales with the quartzites mapped by the Canadian Geological Survey as Huronian. The fossiliferous layers occur a few feet above railroad level. The types were collected by A. F. Foerste in 1912 and form number 8403 and 8403a in the paleontological collections of the Geological Survey of Canada, in the Victoria Memorial Museum, at Ottawa.

Outline closely resembling *Lingula briseis*, Billings, but that species is a much flatter and narrower shell.

Lingula eva, Billings, is similar in the flattening of the median parts and also along the sides; but the sides are diverging rather than parallel anteriorly; nothing is known of the interior. *Lingula vanhorni*, Miller, is more attenuate posteriorly, more rounded anteriorly, and hence has a more ovate form.

2. **Lingula rectilateralis,** Emmons

Lingula rectilateralis was figured by Emmons in the *Geological Report of New York*, published in 1842, on p. 399. The only comment on this figure in the text is: "*Lingula rectilateralis*, is associated with *Triarthrus*." On the same page: *Triarthrus beckii* is stated to be "abundant in gorges at Rodman and Lorraine, and upon the route from Adams to Tylerville, where the (Utica) slate is exposed." From these comments it is concluded that the specimen figured by Emmons came from the horizon of the black shale usually correlated with the Utica, and that it was obtained somewhere in the southern part of Jefferson county.

Regarding this species, Hall made the following observations, in the *Palaeontology of New York*, vol. I, p. 285:

I am unable to perceive any essential differences between this shell and the *L. quadrata* of the Trenton limestone. The figure given by Professor Emmons has the sides straighter and the upper extremity more pointed than the original specimen. In two specimens examined (probably the originals of Fig. 1*a*, and 1*b* on plate 79) there is a slight difference in form, owing in part to compression; but there is no more deviation than is often observed in the same shell in the limestone. The surface is marked by concentric lamellose striae, and the center by nearly equal longitudinal striae; the sides are more or less straight, the base rounded with the upper extremity often subcuneate, having the slopes nearly direct. The base is sometimes nearly straight, and the shell resembles L. Lewisii.

Position and locality. In the soft argillaceous shales in the lower part of the group at Loraine, Turin, and other places.

In the *Catalogue of the Types and Figured Specimens in the American Museum of Natural History*, the original of Fig. 1*a* on plate 79, is stated to have come from the Hudson River (not the Utica) at Lorraine, New York. The rock in which the specimen occurs, however, is sufficiently black to have come from the *Triarthrus becki* zone at the mouth of the Lorraine gorge. In Hall's specimen the anterior is rounded. Radiating lines fine and numerous, successively finer towards the sides of the shell. Apparently with a strong median septum and with cuneate concrete laterals, the anterior part of the middle pair corresponding to the centrals as in the group of shells including the one erroneously identified by Hall as *Lingula quadrata*, also *L. cincinnatiensis* and *L. iowensis*.

In his report on the Lower Siluric Shales of the Mohawk Valley, in *Bulletin 162 of the New York State Museum*, 1912, Ruedemann figures *Lingula rectilateralis* from the Schenectady beds, at the Dettbarn quarry, Schenectady, New York. In the accompanying text he states that Hall cited this species only from the middle and upper Trenton. From this it is evident that Ruedemann had in mind the Trenton species described by Hall as *Lingula quadrata*, and not the lower "Hudson River" form from Lorraine, Turin, and other places, to which Hall also applied the name *quadrata*. Hall refers to *Lingula rectilateralis* only in connection with the Lorraine form, since it was not the Trenton but the later (Utica) form, which had served as a type of the species for Emmons.

At the *Trinucleus* horizon, several hundred yards west of the

railroad bridge, about a mile east of Pulaski, a species of *Lingula* (plate III, Fig. 13) occurs which is distinct from *Lingula rectilateralis.* It is smaller and slightly less quadrangular. If lines are drawn from the beak to the antero-lateral angles, the concentric lines are much more conspicuous on the lateral parts of the shell than on the intermediate portions. The shell is very thin and there is no indication of longitudinal radiating striae along the middle parts of the shell, either on the exterior or interior surfaces. The shell apparently belongs to the group with a long median septum and with concrete laterals, such as are figured by Hall, in his monograph on *Palaeozoic Brachiopoda*, Plate I, Fig. 7, under the name *Lingula procteri*.

The following species were associated with the *Lingula* at the *Trinucleus* horizon, east of Pulaski: *Plectambonites*, *Dalmanella*, *Rafinesquina alternata* of very flat form, *Schizocrania filosa*, *Byssonychia radiata*, *Modiolopsis modiolaris*, *Colpomya pusilla*, *Cuneamya*, *Clidophorus planulatus*, *Archinacella pulaskiensis*, *Cornulites* of straight free form like *Tentaculites*, *Calymene*, and *Trinucleus*.

At the bridge south of Allandale, west of the mouth of the Lorraine gorge, the following species occur in the black shale commonly identified as Utica: *Glossograptus quadrimucronatus*, near mutation *postremus*, *Climacograptus typicalis*, *Mastigograptus* resembling *tenuiramosus*, *Schizocrania filosa*, *Leptobolus insignis*, *Zygospira* of *modesta* type, *Orthoceras*, *Triarthrus beckii*, and *Trinucleus*. This is the fauna usually identified as Utica in these more western areas, and it may be followed up stream into the mouth of the "Gulf." The graptolites were identified by Dr. Ruedemann.

3. **Pholidops subtruncata,** Hall

Pholidops subtruncata was figured by Hall from the exposures at Lorraine, New York. It occurs also east of Lorraine, where the road to Worthville crosses the creek, 2 miles west of the latter village; also northeast of Lorraine, along the creek within the limits of Barnes Corners. It is found also along the river about half a mile below Salmon Falls, a short distance below the level of the base of the Falls.

The name of the species is based upon the straightened anterior margin of the shell in the case of the type specimens. Speci-

mens having the same features occur along the Richelieu River, at Chambly; a very typical example, collected there by A. H. Foord, in 1881, is preserved in the Victoria Memorial Museum, at Ottawa, by the Geological Survey of Canada. It is not so certain, however, that this is a constant feature. The species is very abundant at many localities in the province of Quebec, and has a very considerable vertical range, but the subtruncate anterior margin appears to be an individual characteristic, rather than a prevailing one in the great majority of specimens to be referred to this species. *Pholidops,* apparently of the same type, occurs at various localities within two miles west and northwest of Vars, about 12 miles east of Ottawa, and also a mile west of Edwards station and a mile northwest of Hawthorne station. East of Montreal it occurs at Chambly, and St. Hilaire. Southwest of Three Rivers, it is found along the Nicolet River, southwest of Ste. Monique. Here it ranges from 75 to 1065 feet below the lowest horizon containing *Strophomena planumbona.*

4. **Glyptorthis insculpta,** Hall

The type of the genus *Hebertella* is *Hebertella sinuata,* Hall, from the Maysville division of the Cincinnatian. This type of shell is recognized in the Rogers Gap fauna, beneath the Fulton layer; in the Greendale division of the Cynthiana formation, where one of the species has been described as *Hebertella parksensis;* in the Trenton of central Kentucky, where one form has been described as *Hebertella frankfortensis;* in the Chazy of Canada, where *Hebertella borealis* occurs; and other species no doubt are found in still lower strata. The shell structure is fibrous and impunctate, and the surface is marked by fine concentric striae and lines of growth, but not by lamellose lines of growth. In mature shells, the median part of the brachial valve tends to become elevated anteriorly into a low broad fold which in some species is quite strongly developed.

In another group of shells, however, typified by *Hebertella insculpta,* Hall, the shell structure is not only fibrous and impunctate, but lamellate, and the surface of the shell is marked by lamellose lines of growth. Even in fractured specimens, the lamellose shell structure is readily detected. In the shells of this type, so far seen, there is no tendency toward a median fold in the brachial valve. *Hebertella insculpta* occurs in the Richmond; a

similar form, *Hebertella bellarugosa,* has long been known from the Trenton, Black River, and Stones River groups of the upper Mississippi valley, extending at least as low as the Ridley member of the Stones River, in central Kentucky and Tennessee. In New York, it occurs as low as the middle of the Chazy. From this it will be seen that both lines of descent can be traced back as far as the Chazy, and here they are already as strongly differentiated as at any later time. For the group typified by *Hebertella insculpta,* the name *Glyptorthis* is proposed. In both groups, there are forms in which the median part of the brachial valve is more or less strongly depressed, so as to produce a median sinus, so that the chief distinction of the *Hebertella insculpta* group is, after all, the presence of the concentric lamellose lines of growth, combined with a shell form which otherwise agrees with that of *Hebertella.*

Lamellose lines of growth occur also in species of *Eridorthis,* but in the latter group there is a tendency toward a fasciculate implantation of additional radiating plications, and the brachial valve, in its initial stages, begins with a median groove between two primary depressions, often distinct for a distance of 4 or 5 mm. from the beak, while the anterior half of the shell is marked by a low median fold involving the two median primary plications and 4, 5, or 6 additional implanted plications belonging to the same fascicles. The corresponding parts of the pedicel valve are marked anteriorly by a low median sinus, involving the median fascicle and the first major intercalated fascicle on each side.

In addition to *Hebertella insculpta* and *Hebertella bellarugosa,* the *Glyptorthis* group includes the species figured, but not described by Emmons, under the name *Orthis crispata,* in his report on the Geology of New York, published in 1842. It is possible that *Orthis nisis,* and *Orthis rugaeplicata,* both described by Hall and Whitfield from the Louisville limestone at Louisville, Kentucky, and figured in the *Twenty-seventh Report of the New York State Museum,* in 1875, belong to the same group.

5. **Glyptorthis crispata,** Emmons

(Plate III, Fig. 9.)

In the *Final Report on the Geology of New York,* Part II, published in 1842, Emmons figured a form as *Orthis crispata,* and states that it is associated with a form of *Dalmanella,* which he

figures on the same page as *Orthis testudinaria*, but that it is not so abundant as the *Dalmanella* at Lorraine. The associated form figured from Lorraine as *Pleurotomaria* is a *Hormotoma* of the *sublaxa* type. The *Tentaculites*, said to be more abundant near the upper part of the rock section at Lorraine, is the form with finer longitudinal striae described in this bulletin under *Cornulites*. In the work by Emmons the overlying Oswego gray sandstone is described separate from the Lorraine shales. Earlier in the same part of his discussion, Emmons notes the presence of *Trinucleus* "toward the upper part of the Lorraine shales, in a very fine bluish slate. The bed was exposed in repairing a mill dam near the center of Lorraine." Other species from the *Orthis crispata* horizon, northeast of the bridge in Lorraine, are: the so-called *Heterocrinus* and *Glyptocrinus* columnals, *Pholidops subtruncata, Plectambonites, Rafinesquina alternata* of very flat form, *Catazyga erratica, Cyrtolites ornatus, Archinacella pulaskiensis, Byssonychia radiata, Modiolopsis* belonging to the *concentrica* group, *Colpomya pusilla, Cuneamya* resembling the form here described as variety *brevior, Clidophorus planulatus, Ctenodonta lorrainensis, Lyrodesma poststriatum*, and *Calymene*.

Orthis crispata occurs also half way between Lorraine and Worthville, at the locality described elsewhere in these pages as 2 miles west of Worthville. Here it is associated with: the columnals usually referred to *Heterocrinus* and *Glyptocrinus, Pholidops subtruncata, Dalmanella, Catazyga erratica, Protowarthia, Cyrtolites ornatus, Hormotoma* belonging to the *sublaxa* variety, *Cornulites* having the appearance of *Tentaculites, Byssonychia radiata, Colpomya pusilla, Cuneamya*, apparently *Ischyrodonta unionoides, Clidophorus planulatus, Ctenodonta lorrainensis, Lyrodesma poststriatum, Calymene, and Trinucleus.*

The following is a description of *Orthis crispata*, drawn chiefly from specimens obtained 2 miles west of Worthville, on the road to Lorraine, since here the best preserved specimens were found.

Largest pedicel valve found, 17 mm. in length and at least 20 mm. in width, the lateral margins being not well preserved on one side. Largest brachial valve found, 12 mm. long and 16 mm. wide. The convexity of the pedicel valve was 4 mm., and that of the brachial valve 2 mm.

Pedicel valve more convex than the brachial valve, the greatest convexity being reached about a fourth of the length of the shell

from the beak. Cardinal area fully 2.5 mm. in height in the larger valves. Muscular area not obcordate, but narrowed anteriorly so as to give the deepest part of the area a rounded rhomboidal form with the greater axis extending parallel to the length of the shell. Adductor impressions occupying almost one-third of the width of the area, distinctly limited as far as the beak. Anterior to the middle of the adductor impression, there is a narrow thickening of the shell along the middle line, but this can be traced only a short distance. Laterally and antero-laterally from the muscular area there are long and rather distant radiating striae, usually called ovarian markings, but these rarely are preserved.

Brachial valve moderately and rather evenly convex. Cardinal process long, narrow, and thin. Crural plates strongly defined and terminating in sharp points. Anterior to the cardinal process the shell is thickened so as to produce a low broad elevation extending slightly farther than the anterior edge of the posterior adductor impressions. The posterior adductor impressions are only faintly delimited, and the anterior ones not at all, in the specimens seen so far.

Surface marked by rather angular plications, increasing by intercalation, about 5 or 6 in a width of 5 mm. along the anterior margin of the shell. Concentric striae lamellose, varying from 8 in a length of 4 mm. near the middle of the shell, occasionally to 12 in the same length near the anterior margin.

6. **Dalmanella centrilineata,** Hall

The types of this species were found, associated with *Trinucleus* and *Dalmanella,* at Lorraine. If our interpretation of this shell is correct, it is nothing but a small form of the ordinary *Dalmanella* so common at Lorraine, Pulaski, and elsewhere in the New York Lorraine. It is not mentioned by Hall and Clarke in their monograph on Palaeozoic Brachiopoda, in vol. viii of the *Paleontology of New York.*

7. **Strophomena planumbona,** variety

(*Plate II, Figs. 4 A, B*)

A species of *Strophomena,* (plate II, Fig. 4 A) belonging to the *planumbona* group, but subtriangular in outline, is labelled as

coming from Chambly on the Richelieu River and as collected by Foord in 1881. The same slab contains *Glossograptus* (*Orthograptus*) *quadrimucronatus-approximatus,* Hall and *Cymatonota recta,* Ulrich. The specimen is a pedicel valve 22 mm. long and 32 mm. wide, exposing the interior and, by exfoliation, also a cast of a part of the exterior. The lateral margins form angles of about 70 degrees with the hinge-line, produced to an angle of 50 degrees on one side by the lateral extension of the shell along the hinge-line. Width of muscular area 9 mm., length 7 mm., with a broadly rotund outline. The posterior diductor scars form a narrow strip only 1 mm. in width along the upper half of the lateral margin of the muscular area. The anterior diductor scars are much wider and do not show conspicuous flabellate markings. The adductor scars have a total width of 1.8 mm., being divided as usual along the median line by a prominent striation. Interior of shell only moderately thickened along the anterior border, the anterior half and the marginal parts laterally being crossed by radiate vascular markings which are only moderately conspicuous. The entire inner surface, aside from the muscular area, covered by a fine shagreen consisting of numerous minute granules visible under a lens. Exterior of pedicel valve evidently covered with finer radiating striae than those on the brachial valve, every fourth or sixth one tending to be slightly more conspicuous.

Two brachial valves, evidently belonging to the Chambly species occur among a group labelled as coming from the Riviere des Hurons, however, since the individual specimens are not labelled separately, there has been ample opportunity during the moving of collections, to mingle specimens from different localities, so that there is no absolute certainty that the two brachial valves in question came from the Riviere des Hurons. As far as their lithological appearance is concerned, they may have come from the Chambly locality. The brachial valve here figured (plate II, Fig. 4 B) is associated in the same slab with *Cleidophorus praevolutus,* and the other specimen is associated with *Rafinesquina mucronata.* It will be noted that in the *Report on the Geology of the Montreal Sheet,* by R. W. Ells, published in 1896 by the Geological Survey of Canada, Dr. Henry M. Ami lists *Strophomena* from the collections made at Chambly by W. E. Deeks in 1890, while no mention is made of the occurrence of *Strophomena* along the Riviere des Hurons. These brachial

valves show a convexity of about 7 or 8 mm., their greatest convexity being anteriorly, where the shell is deflected toward the anterior and antero-lateral margins. The radiating striae vary in size, three finer striae being intercalated between each pair of more conspicuous striae over the greater part of the valve, but along the anterior margin the intermediate striae become more conspicuous so that the difference in size is less noticeable. Here about 16 striae are seen in a width of 5 mm. Very fine concentric striae, seen only under a lens, are clearly indicated. Along the hinge-line there is a tendency toward wrinkling, the wrinkles being more perpendicular toward the beak and more oblique toward the postero-lateral angles. The wrinkling does not extend over the middle parts of the shell as in *Strophomena fluctuosa*. Interiorly, the central parts of the shell present a few vascular markings, rather inconspicuously developed, while laterally there are numerous radiating lines suggesting relationship to the so-called ovarian markings more conspicuously developed in other shells. The entire inner surface is covered with a fine shagreen, or by numerous minute granules seen only under a lens.

The occurrence of these specimens of *Strophomena* in the Lorraine areas east of Montreal is especially interesting in view of the entire absence of the *planumbona* group of *Strophomena* in the Maysville beds of the Cincinnatian province.

All of the specimens here described are preserved in the Victoria Memorial Museum, at Ottawa, by the Geological Survey of Canada. The original of Fig. 4A is numbered 8404, and that of Fig. 4B, 8405.

It is scarcely necessary to state that this occurrence of *Strophomena* of the *planumbona* type on the Richelieu River, at Chambly village is regarded as belonging more than 500 feet below the lowest horizon at which *Strophomena planumbona* occurs associated with *Rhynchotrema perlamellosa,* in the Richmond along the Nicolet River. A brachial valve of *Strophomena* was found also along the Nicolet River, at the highest *Leptaena rhomboidalis* horizon, in the lower part of the Proetus zone. Here it was associated with *Pterotheca pentagona,* a form described from Chambly. These occurrences of *Proetus, Leptaena, Strophomena,* and *Pterotheca* are noteworthy, since none of these genera are known in the Lorraine of New York.

8. **Rafinesquina nasuta,** Conrad

(*Plate III, Fig. 2 A, B; Plate IV, Fig. 2 C*)

Rafinesquina nasuta was described by Conrad, in the *Journal of the Academy of Natural Sciences of Philadelphia,* vol. VIII, part II, p. 260, in 1842, as follows:

> Triangular; longer than wide, slightly winged; inferior valve with the umbo and disk flattened; toward the base, suddenly and concentrically bent towards the upper valve; concentrically wrinkled; radii distinct, rather remote, with three or four minute intermediate lines; base projecting and angular in the middle.
>
> *Locality.* Near Rome, Oneida county, New York.
>
> This species resembles *S. alternata,* and *S. deltoidea* in having one or two of the central lines larger than the rest, but it is a much flatter and proportionately longer shell.

This horizon at Rome furnishes the types also of *Ischyrodonta curta, Lyrodesma plana, Pterinea demissa,* the forms of *Modiolopsis* for which Conrad proposed the term *angustifrons* but which Hall included in *M. modiolaris,* and *Orthodesma nasutum.* The horizon is about equivalent to that at Bennett bridge, one mile down stream from the Salmon river falls.

In the *Paleontology of New York,* vol. I, on plate 79, Hall represented similar forms, as found at Pulaski, suggesting the extremes of variation. Specimens of this type are common at one ferruginous horizon near the upper part of the *Trinucleus* zone, west of the railroad bridge, about a mile east of Pulaski. In one rock boulder found by Dr. E. O. Ulrich, a short distance west of the bridge, there were at least 100 valves of *Strophomena nasuta,* crowded together at all sorts of angles. In the majority of these the anterior nasute part was narrower than in Fig. 2*b* of Hall, although wider than in Fig. 2*a,* and the degree of inflection producing the nasute fold was intermediate to that shown by these figures. In the same rock boulder occurred *Dalmanella, Plectambonites, Cyrtolites ornatus, Byssonychia radiata, Modiolopsis modiolaris, Calymene and Trinucleus.*

A nasute form of *Rafinesquina* was found also in the stream bed at Barnes Corners, associated with *Pholidops, Plectambonites, Rafinesquina mucronata,* a flat form of *Rafinesquina alternata, Dalmanella, Archinacella pulaskiensis, Hormotona, Byssonychia radiata, Modiolopsis modiolaris, Colpomya pusilla, Cuneamya,*

Clidophorus planulatus, Orthoceras lamellosum, Cornulites of straight free type, resembling *Tentaculites, Calymene,* and *Trinucleus.*

Another nasute form of *Rafinesquina* was found at Worthville, associated with *Plectambonites, Dalmanella, Byssonychia radiata, Modiolopsis modiolaris, Orthodesma nasutum, Clidophorus planulatus, Ctenodonta lorrainensis, Lyrodesma poststriatum, Hormotoma, Cyrtolites ornatus, Cornulites* of straight free type, resembling *Tentaculites, Calymene,* and *Trinucleus.*

It is not likely that these nasute forms constitute a species distinct from *Rafinesquina alternata* as identified from the same beds, but their distribution at about the same horizon is possibly of significance for stratigraphic purposes.

Rafinesquina alternata was figured by Emmons from the Trenton of New York and the Trenton form is to be regarded as the type of the species. With this Trenton form it has been customary to identify all related forms in later rocks, up to the close of the Richmond. The discrimination of these forms into species and varieties is highly desirable.

9. **Rafinesquina squamula,** U. P. James

(*Cincinnati Quarterly Journal of Science, vol. 1, p. 335, 1874*)

Shell small, thin, semi-oval in outline, broader than long; hinge-line varying from a little more to a little less than the greatest breadth of the shell farther forward.

Dorsal valve slightly concave or nearly flat; cardinal line straight; cardinal area linear; a slight depression immediately forward of the beak. Surface covered, with fine, rounded radiating striae of nearly uniform size, increased toward the free margin by bifurcation.

Ventral valve slightly convex; beak and hinge-line slightly projecting; cardinal area narrow, a little the widest in the middle; foramen triangular and nearly closed by the cardinal process of the other valve; a strong mesial rib extending from the beak to the front; surface covered by fine, rounded, radiating striae, which bifurcate once or twice before reaching the free margins; the striae starting at and near the beak more prominent than the branching ones; crossed by very fine concentric lines, visible only

under a good magnifier, and even then in some cases quite obscure. Visceral space very little, the valves being so closely drawn together, translucent. Interior not observed.

Breadth of a full-sized specimen, $\frac{5}{8}$ inch; length, $\frac{1}{2}$ inch.

Position and locality. Cincinnati Group, about 350 feet above low watermark of the Ohio River, at Cincinnati.

Collected by U. P. James.

10. **Rafinesquina mucronata,** sp. nov.

(*Plate II, Figs. 7 A, B*)

Shell small, the length about three-fifths of the width, but varying in different individuals. Usually slightly extended along the hinge-line beyond the middle width of the shell so as to produce a small mucronate projection; but some individuals have rectangular posterolateral outlines. Usually obliquely wrinkled along the hinge-line. Radiating striae fine, with every fourth one distinctly more conspicuous along the middle and anterior parts of the valve; usually the stria found along the median line of the shell is more conspicuous than any of the remainder. Pedicel valve only moderately convex, the brachial valve slightly concave, almost flat.

Locality. Along the Nicolet River, southwest of Ste. Monique, from 80 to 870 feet below the lowest strata containing *Strophomena planumbona.* As type forms, those occurring between 80 and 530 feet below the lowest *Strophomena planumbona* horizon are selected. Here they occur associated with forms resembling *Whiteavesia pholadiformis, Modiolopsis concentrica,* and *Catazyga erratica.* In the underlying beds, *Proetus* becomes common. It occurs in the *Proetus* zone also at Chambly.

The specimens here figured were obtained west of Vars, at a locality found by going about a mile west from the station, along the railroad, and then a third of a mile northward along the road. Here it also is associated with *Catazyga.* It occurs also a mile farther north, at the first cross roads, and also along the railroad about a mile northwest of Hawthorne station.

The species appears closely allied to *Rafinesquina squamula,* James, from the Fairmount beds in the lower part of the Maysville division of the Cincinnatian strata in Ohio. The latter,

however, is not so characteristically mucronate at the ends of the hinge-line, nor so characteristically obliquely wrinkled along this posterior margin. Since the original description of *Rafinesquina squamula* is not readily accessible, it is here reprinted.

11. **Catazyga erratica,** Hall

Catazyga erratica, or rather *Orthonomaea erratica,* was described from drift material collected in Wayne or Monroe counties. It was reported by Hall from near Washingtonville, in Oswego county. Very typical specimens occur a short distance down stream from the railroad bridge, about a mile east of Pulaski. It occurs also at Lorraine village, a mile south of Barnes Corners, 2 miles northeast of Lorraine on the road to Worthville, and, at a higher level, about half a mile down stream from Salmon River Falls. If this species was found by Conrad it must have been included in the group identified by him as *Delthyris striatula,* under which name he listed chiefly the common *Dalmanellæ* of the New York Trenton and Lorraine. Washingtonville was located on Little Sandy creek. It was the type locality also for *Cyrtolites ornatus.* Hall listed from this locality also *Byssonychia radiata, Modiolopsis modiolaris, Clidophorus planulatus, Hormotoma gracilis, Ormoceras crebriseptum,* and *Rafinesquina alternata,* indicating that the exposures at Washingtonville correspond approximately to those east of Pulaski, near the railroad bridge.

Species of *Catazyga* occur at numerous localities in the province of Quebec in Canada. The various forms can be distinguished readily only when good specimens, preserving the original curvatures of the valves, are present. Flattened shells may be recognized readily generically, but the more exact specific determinations may be impossible. Usually, it is assumed that specimens occurring at the Richmond horizons belong to *Catazyga headi,* while those at lower horizons, in the Lorraine, all belong to *Catazyga erratica.* This, however, requires verification.

Catazyga occurs at various localities east of Ottawa. About a mile west of Edwards station, it occurs along a small stream southeast of a church located south of the pike. It formerly occurred along the railroad about a mile northwest of Hawthorne. Three-fourths of a mile west along the railroad, from Vars, and then half a mile northward, it occurs along the country road. A quar-

ter of a mile south of the railroad, along the same road, it is associated with *Strophomena fluctuosa*. All of these forms are regarded as *Catazyga headi*, although only at the last mentioned locality the associated fauna was regarded as Richmond.

Along the Nicolet River, southwest of Ste. Monique, *Catazyga* occurs at many horizons. The first specimens, in descending order, are met 97 feet below the top of the fossiliferous part of the Richmond, below the level of the red Queenstown shale division. It occurs also 7, 33, 44, 56, and 60 feet below this highest *Catazyga* level. At the top of this zone, 44 feet below the top, and at the base, *Catazyga* is associated with *Strophomena planumbona*. At the base, *Rhynchotrema perlamellosa* also is present, and the zone is included in the Richmond section, being regarded, together with the overlying fossiliferous part, as approximately equivalent to the Waynesville member of the Richmond. *Catazyga* is common also 4 feet below the lowest *Strophomena planumbona* zone, and, again, at 77 feet. At various levels, between 77 and 220 feet below the lowest *Strophomena planumbona* layer, *Whiteavesia pholadiformis* and a form resembling *Modiolopsis concentrica*, occur loose in strata which evidently were derived from this interval. Loose fragments of rock containing *Catazyga* occur at various intervals between 77 and 533 feet below the lowest *Strophomena planumbona* horizon, but in this interval *Catazyga* is very rare.

At the 533-foot level, *Catazyga* occurs associated with *Proetus*, this being the highest level for that trilobite, at this locality, but the *Catazyga* is not abundant until a level 580 feet below the lowest *Strophomena planumbona* is reached. At the 820-foot level, the first specimens of *Leptaena*, belonging to the *rhomboidalis* group, are seen, in descending order. Between the 580 and 820-foot levels, *Catazyga* occurs at numerous horizons, but is common only at the 650, 693, and 710-foot levels. *Proetus* occurs at numerous levels between the 533 and 820-foot zones. It is with this part of the Nicolet River section that the Chambly village exposures are correlated, while those exposures which contain *Whiteavesia pholadiformis* and the form resembling *Modiolopsis concentrica*, in the absence of *Proetus*, are correlated with that part of the Nicolet River section which lies between the 77 and 220-foot levels. The exposures along the road, half a mile south of the station at St. Hilaire, probably belong here.

Proetus ranges from the 533 to the 1002-foot levels, in descending order. At the 820-foot level, the *Pterotheca pentagona,* here described, was found. *Leptaena* occurs also at the 1284, 1338, 1515, 1699, and 1878-foot levels. Above the highest *Leptaena* horizon, at the 820-foot level, all of the forms of *Catazyga* resembled *Catazyga headi.* Between the 820 and the 1284-foot levels no specimens of *Catazyga* were noticed. At the 1284-foot level some poor specimens of *Catazyga* were found which could be identified only generically. *Catazyga erratica* was identified with certainty only at the 1390-foot level. The first specimens of *Trinucleus,* in descending order, are found at the 1552-foot level, and it has been followed below this level, at various intervals for fully 800 feet without reaching the base of its range in these strata. *Triarthrus* is known at present only from the 1653-foot level. The association of *Triarthrus, Trinucleus,* and *Leptaena,* seen on the Yamaska River, northwest of St. Hugues, is correlated provisionally with this 1653-foot horizon in the Nicolet River section. This, probably, is the horizon also of the exposures on the Becanceur River, about a mile and a half east of Breault station. The exposures southwest of Petite Caroline, containing *Leptaena,* and reported to contain *Trinucleus,* apparently belong somewhere between the 1550 and 1880 foot levels. The exposures at St. Hyacinthe are regarded as lower than anything studied so far along the Nicolet River, and those at St. Augustin and at the Montmorency Falls are regarded as far lower.

A considerable part of the fauna collected along the Riviere des Hurons, west of St. Jean Baptiste, has not been recognized as yet elsewhere. Owing to the presence of *Whiteavesia* of the *pholadiformis* group, and the absence of *Proetus,* however, these strata are correlated with the upper part of the Nicolet River section, somewhere between the 77 and 220-foot levels. It should be remembered, however, that *Whiteavesia* of the *pholadiformis* type occurs also at Chambly, and that the presence of a fossil is a safer guide to its stratigraphical position, than the absence of an expected form.

12. **Caritodens demissa,** Conrad

(*Plate I, Fig. 10; Plate III, Fig. 11*)

The specimen of *Pterinea demissa* here figured, from the Riviere des Hurons, presents the following characteristics. With increasing age the sinuosity of the anterior margin of the shell becomes more pronounced, the angle between the anterior margin of the ear and body increasing from less than 25 to frequently more than 55 degrees. This is due chiefly to a retardation of growth of the anterior margin of the body below its junction with the ear, and an acceleration of growth along the basal margin. A similar retardation of growth takes place along the line of junction of the posterior margin of the body with the wing. The result is that the anterior margin of the body becomes more erect, the shell is strongly prolonged in the direction of the basal margin, assuming a more oblong form, and the general appearance is that of a less oblique shell. In the meantime there is a considerable prolongation of the shell along the hinge-line, both anteriorly and posteriorly, these parts, usually, however, not being well preserved. In the fine-grained Lorraine sandstones, near Vars, east of Ottawa, the surface ornamentation is preserved in the form of fine, sharp, concentric striae, separated by much broader, flat, concentric spaces. Judging from well preserved specimens found in clays of the Richmond formation, on the Nicolet River, the sharp striae may have served as lines of support for narrow lamellose extensions of the shell, 0.5 mm. or less in width.

The shell substance evidently consists of two layers, of which the outer layer is very thin, rarely more than 0.25 mm., and often less in thickness; the inner layer frequently attains a thickness of 1 mm., and sometimes exceeds even 2 mm. in thickness. Specimens preserving both the outer and inner layers are common in the Richmond beds along the Nicolet River, several miles southeast of Ste. Monique, in the province of Quebec. In these specimens, the thick, inner layer appears to have undergone secondary crystallization; it is whitish in color, of loose texture, and probably dissolved readily under most conditions attending fossilization, since this layer so rarely is seen; its outer surface, where overlaid by the thin outer layer, is smooth, not showing the concentric striae belonging to the outer surface of the outer layer. The

outer layer is dark in color and dense in texture. This is the layer most frequently preserved, when any part of the shell is present. Shells in which the thick inner layer has disappeared usually do not present any trace of the inner surface of the valves so that the inner surface has long been unknown. Many strange things, however, may happen during the processes of fossilization. In the case of *Pterinea demissa,* when found in fine-grained sandstones, it occasionally happens that the rock, when split open, exposes on one piece the impression of the exterior of a valve, and on the other piece the impression apparently of the interior; but only the most pronounced features of the interior are retained, usually the crural ridges forming the jugum, to be described later, and the inner outline of the ligamental area. Superposed upon this cast of the inner surface of the valve are traces of the concentric, striate structure belonging to the outer surface of the valve, especially along the body of the valve.

The interior of the left valve, in one specimen from the Richmond strata along the Nicolet River, is characterized by a longitudinally striated ligamental area, 2.5 mm. in height near the beak. About 2 mm. below the lower edge of this ligamental area, a short distance posterior to the beak, the inner edge of the jugum is located. This is a lunate callosity or thickening of the interior of the shell a short distance below the ligamental area, the concave side facing the middle parts of the valve, the posterior extension curving away from the ligamental area, following approximately the line of junction between the body of the valve and the posterior wing, while the anterior crural ridge or anterior part of the jugum extends for only a short distance along the line of junction between the body of the valve and the anterior ear. This jugum is that part of the inner surface of the valve most commonly indicated in casts of the interior of the shell. Between the inner edge of the jugum and the lower margin of the ligamental area the shell is thickened. Transverse to this thickening, below the beak, there are several ridges serving as anterior cardinal teeth. In fact, the posterior extension of the jugum serves as a posterior lateral tooth. Nothing similar to this structure is known in the case of *Glyptodesma.* The nearest approach is seen in the shell described by Hall as *Pterinea flabella* from the Hamilton group of New York (*Paleontology of New York,* vol. V, part I, plate XIV, Fig. 19, and plate XV, Fig. 5). The posterior muscular scar is large and lies

a short distance below the termination of the posterior lateral tooth. The impression is very shallow and usually but faintly outlined. The pallial line also is faint. No trace of an anterior muscular scar has been noticed so far. The location for this scar should be just below the anterior termination of the jugum. It should be noted that the posterior crural ridge, forming the posterior half of the jugum of the right valve is exactly opposite the posterior crural ridge of the left valve, in this respect not fitting the ordinary conception of a tooth among the pelecypods.

The shell of the right valve frequently is as thick as that of the left valve, and it is similar structurally, but the valve is only slightly convex toward the beak, and becomes flattened, or even slightly oblique, toward the basal parts of the shell.

The specimen here figured, from the Riviere des Hurons, near St. Jean Baptiste, was collected October, 1872, by Thomas Curry. It is associated in the same slab with *Cymatonota recta,* Ulrich, *Byssonychia radiata,* Hall, *Cleidophorus praevolutus,* Foerste, and *Lophospira bowdeni-beatrice,* Foerste. It is numbered 8429, and is preserved by the Geological Survey of Canada in the Victoria Memorial Museum, at Ottawa. A younger specimen, No. 8433, from the same locality is represented by Fig. 11 on plate III.

The shell now known as *Pterinea demissa* was originally described by Conrad, *Journal of Academy of National Sciences, Philadelphia,* 1842, p. 242, plate 13, Fig. 3.) from the Lower Silurian sandstone near Rome, in Oneida county, New York. Here it was found associated with *Rafinesquina nasuta,* Conrad, in the quarries exposing the lower part of the grey sandstone overlying the Lorraine shales. The specimen figured by Conrad was a young individual, with a height from the ventral margin to the hinge-line of only 27 mm.

Along the Nicolet River, in the province of Quebec, *Pterinea demissa* is very common at several horizons in the Richmond. It occurs also at various horizons in the upper 500 feet of the underlying Lorraine section. It is found at Chambly, on the Richelieu river, and probably ranges throughout the *Proetus* division of the Lorraine in this part of Canada, although by no means as common in the Lorraine as in the Richmond. Small specimens occur half a mile south of the railroad station at St. Hilaire.

Specimens of *Pterinea demissa* occur at numerous localities within 12 miles east of Ottawa. Three-quarters of a mile west of

Vars, along the railroad, and then a third of a mile northward along a country road, it is found in the *Proetus* zone. Small specimens occur in the *Proetus* zone also a mile northwest of Hawthorne station, along the railroad. It occurs also over a mile west of Edwards station, along a creek southeast of a church on the Ottawa pike, associated with the following fossils: columnals usually referred to *Heterocrinus* and *Glyptocrinus*, *Pholidops subtruncata*, *Dalmanella*, *Hebertella*, *Plectambonites*, *Zygospira modesta*, *Byssonychia radiata*, *Cornulites*, and *Acidaspis*. Mr. W. R. Billings showed me a *Catazyga headi* said to have been obtained here.

Going from Vars about three-quarters of a mile westward, and then a quarter of a mile southward to a point where the road crosses a small stream, *Pterinea demissa* is found at a horizon provisionally regarded as Richmond, owing to the presence of the Richmond form of *Strophomena fluctuosa*. The remainder of the fauna consists of the following species: *Pholidops subtruncata*, *Crania*, *Lingula*, *Rafinesquina alternata* of flat form and fully 30 mm. in length, *Plectambonites*, *Catazyga headi*, *Zygospira modesta*, *Clidophorus* resembling *praevolutus*, *Byssonychia radiata*, *Modiolopsis* belonging to *concentrica* group, *Whiteavesia pholadiformis*, *Rhytimya*, *Lophospira* belonging to *bowdeni* group, *Cornulites* both attached and curved, and also straight and free, *Orthoceras*, *Bythocypris cylindrica*, *Calymene*, and *Isotelus*.

A third of a mile south of the *Strophomena fluctuosa* locality there is a cross road, near which, a short distance westward, a farm lane, formerly an open road, turns off southwards, and about half a mile down the lane reaches the highest fossiliferous strata of the Richmond, directly beneath the Queenstown shales. Residual blocks here contain *Pterinea demissa* associated with *Byssonychia radiata*, *Hebertella* resembling *occidentalis*, and numerous specimens of a *Zygospira* resembling *kentuckiensis*.

In the Cincinnatian areas of Ohio, Indiana, and Kentucky, *Pterinea demissa* also is much more common in the Richmond than in the Maysville. It appears absent in the Eden, but similar specimens occur in the Greendale and Rogers Gap divisions of the Cynthiana formation in Central Kentucky.

For *Pterinea demissa*, as identified from the lower Richmond strata of Ohio, the generic term *Caritodens* was proposed by the writer.[2] These Ohio specimens retained only the thin outer layer

[2] *Bulletin of Denison University*, vol. xvi, p. 71, 1910.

of the shell, and, therefore, did not exhibit the longitudinally striated ligamental area. It is evident now that the flexure of the outer layer of the shell, along the hinge-line, has no connection with the method of attachment of the valves to each other. The so-called single prominent linear posterior tooth in each valve is the posterior crural ridge or posterior half of the jugum.

13. **Byssonychia radiata,** Hall

(*Plate III, Figs. 12 A, B, C*)

Byssonychia radiata was described from the Lorraine of New York, and various specimens from the Cincinnatian of Ohio, Indiana, and Kentucky were identified with it. Among the Lorraine localities are mentioned: Boonville and Turin, in Lewis county; at Lorraine, Jefferson county; at Pulaski, Washingtonville and Mexico, Oswego county; near Rome, in Oneida county; but Fig. 4*a* on plate 80, accompanying the original description, in the *Paleontology of New York,* vol. I, represents a specimen obtained at Pulaski, and this is regarded as the type, while the specimen illustrated by Fig. 4*b,* obtained from an unknown locality in the same county, is regarded as the cotype.

Fig. 4*b* comes nearest to presenting the correct outline of the shell, especially those with the average number of plications. The upper part of the anterior margin is slightly concave owing to the forward curvature of the shell at the beak and the incurvature of the anterior face of the shell toward the byssal opening. The upper part of the umbonal ridge is never angular as in *Byssonychia richmondensis.* The angle between the anterior face and the cardidinal margin usually varies between 85 and almost 90 degrees, but occasionally is as low as 80 degrees. The length of the cardinal margin usually is about half the greatest length of the shell, from the beak toward the posterior part of the nearly evenly convex basal margin. Occasionally, the cardinal margin equals about three-fifths of the greatest length of the shell. The ratio of the greatest width to the greatest length, measured diagonally across the shell from the beak to the posterior part of the basal margin, usually is about 77 per cent, but may vary from as low as 70 to as high as 81 per cent. The convexity of the single valve usually does not exceed 6 mm. in a shell having a maximum length of 36 mm. Shells exceeding 40 mm. in length are rare.

The number of radiating plications appears to vary considerably. If only those shells are selected in which both the cardinal margin and the anterior face are well exposed, then 45, 46, or 47 radiating plications are very frequent. However, specimens occur in which the number of plications is as great as 55. In the specimens with 45 radiating plications, these plications are distinctly broader than the intervening grooves; in those with 55 plications, the width of the latter exceeds that of the intervening grooves only slightly, if at all. Since the number of plications is considered as of diagnostic value in the genus *Byssonychia*, an attempt was made to discriminate two species among these Lorraine forms from Pulaski, but without success. Some of the forms with the greater number of plications are slightly more erect and somewhat longer along the hinge-line, but others have the larger number of plications without differing in form or outline from those specimens in which the number of plications is smaller, and, of course, specimens with intermediate numbers occur. At Pulaski, specimens with about 45 plications are rather abundant both in the gorge south and southwest of the town, and also along the river banks eastward, as far as the railroad bridge. Specimens with 55 plications occur, associated with the others, at the *Trinucleus* horizon, several hundred yards west of the railroad bridge. In none of the specimens does the posterior margin meet the cardinal line as in the illustration of *Byssonychia praecursa*, Ulrich, on plate 45 of the *Geology of Ohio*, vol. VII. The angle is much more obtuse, the posterior margin, in most specimens, rounding almost gradually into the cardinal outline.

The statement by Hall that *Byssonychia radiata* has 25 to 40 plications probably indicates that he had specimens with 45 plications in his possession, those on the anterior face not being well exposed. The specimen illustrated by Fig. 4*a*, on plate 80, of the *Paleontology of New York*, vol. I, was examined for me very obligingly by Dr. Chester A. Reeds, and found to possess 48 radiating plications. The original of Fig. 4*b* exposes 42 plications and about 6 are still covered by rock. In 4*f*, 50 plications are certain. In 4*c*, 28 plications are visible but additional ones are present but not exposed. See Fig. 12*c*, pl. III, this BULLETIN.

The vertical range of *Byssonychia radiata* is considerable. It occurs at Bennett bridge, and also half a mile eastward up the river, and the same distance west of the Salmon River Falls.

It occurs also at lower horizons than those exposed at Pulaski; for instance in the Lorraine Gulf, where it was cited by Emmons from within 4 feet of the upper part of the Triarthrus zone.

Along the Nicolet River, in the province of Quebec, *Byssonychia radiata* ranges through the *Proetus* zone and downward into the upper part of the *Trinucleus* zone. Upward, it appears to range as far as the upper parts of the fossiliferous Richmond, just beneath the Queenstown shale, but this requires confirmation since the Nicolet River section was studied before numerous typical specimens from the Lorraine of New York were at hand.

14. **Colpomya faba-pusilla,** var. nov.

(*Plate II, Fig. 10; Plate III, Fig. 4 A, B*)

Greatest length of largest specimens known about 10 mm., cardinal margin straight for a distance of about 5 mm. posterior to the beak, rounding into the oblique posterior margin of the shell. There is considerable variation in the obliquity of this posterior margin; in the shells having a more vertical posterior margin, the length of the straight hinge-line posterior to the beak may equal nearly 6 mm., while in the shells having a strongly oblique posterior margin the straight hinge-line may extend but slightly more than 4 mm. beyond the beak. Mesial sulcus strongly defined from the beak to the basal margin, its deepest part forming an angle of about 70 degrees, varying in some shells to 60 degrees, with the cardinal outline. Anterior to the mesial sulcus the shell is only moderately convex. Posterior to this sulcus, however, along the umbonal ridge, the shell is strongly convex, this convexity becoming almost angular toward the beak. The angle between the umbonal ridge and the cardinal margin varies usually between 40 and 45 degrees. Anterior margin more narrowly rounded, extending about 2 mm. anterior to the beak.

Maximum length, measured diagonally, 10 mm.; height posteriorly, between 5.5 and 6 mm.; height at the beak, about 4.5 mm., but varying from a little less to a little more than this height; convexity of the single valve, about 1.75 mm. in shells showing the strongest convexity.

Surface with very fine concentric striae, visible under a lens. Interior with a small muscular scar near the upper anterior margin;

hinge unknown, and hence the generic reference is based merely upon the general appearance of the exterior of the shell.

Locality. At the *Trinucleus* horizon, several hundred yards west of the railroad bridge, east of Pulaski, New York. The same form is found also at the eastern edge of Lorraine village and at the road crossing over the creek, two miles west of Worthville, in the same state.

The original of Fig. 10 on plate II, since lost in the Dayton flood, was collected by Aug. F. Foerste, in 1912, on the Richelieu River, at Chambly, associated in the same rock fragment with *Catazyga headi* and *Proetus.* An impression of the same species from the same locality, numbered 8430, is preserved in the Victoria Memorial Museum at Ottawa, Canada.

Modiolopsis faba, (Conrad) was figured by Emmons[3] from the black irregular-bedded limestone at Watertown, New York, where it was said to be abundant. His figure most closely resembles Fig. 6*a* on plate 35, in vol. I, of the *Paleontology of New York.* In this volume the horizon is described as belonging to the concretionary layers of the Trenton limestone, at Watertown. This would place it in the basal Trenton. Compared with typical *Colpomya faba,* the valves of *Colpomya pusilla* are relatively higher posteriorly and lower at the beak, owing to the stronger divergence of the basal margin from the cardinal outline, amounting frequently from 30 to 35 degrees. The beak projects more distinctly above the cardinal margin, and the cardinal part of the anterior margin rises more nearly to the level of the straight cardinal outline of the shell posterior to the beak. The mesial sinus begins at the beak as a depression near the middle of the umbones; it tends to be more oblique than in *Colpomya faba,* but, as a matter of fact, the Lorraine form is scarcely distinguishable from the Trenton types.

The Lorraine form was figured by Hall from casts in the sandstone layers forming part of the section at Pulaski, New York. The specimen represented by Fig. 4*a* on plate 82 of vol. I, of the *Paleontology of New York,* forms No. 736–4, in the American Museum of Natural History. Fig. 4*b,* on the same plate, unquestionably represents the same species, although the original of this figure has been lost.

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[3] *Geological Report,* New York, 1842, p. Fig. 5.

15. **Pholadomorpha pholadiformis,** Hall.

(*Plate II, Fig. 16; Plate V, Fig. 4*)

Cardinal and basal margins diverging at an angle of about 20 degrees. Basal margin almost straight; at a point almost vertically beneath the beak it rises gradually toward the strongly rounded anterior margin. The latter extends 12 mm. anterior to the beak. Posteriorly the cardinal margin is fairly straight for about 35 or 40 mm. and then rounds gradually into the very oblique posterior margin, forming an angle of about 130 or 135 degrees with the latter. The margin is strongly rounded at the posterior extremity of the umbonal ridge. The umbonal ridge is low and very broad; it is moderately distinct for a distance of nearly 30 mm. from the beak, but merges into the general convexity of the shell posteriorly. From this umbonal ridge the slope toward the basal margin and toward the cardinal margin is rather flat. There is no mesial sinus anterior to the umbonal ridge. The shell is concentrically striated. These striae are most distinct along the anterior half, below the umbonal ridge, and along the posterior half, above this ridge, where the low transverse plications are less distinct or absent. The transverse plications cover the slope beneath the umbonal ridge almost as far to the front as the area beneath the beak, although anteriorly these plications no longer reach the basal margin of the shell. They are approximately vertical to the basal margin, although curving moderately forward on approaching the umbonal ridge. Similar low transverse plications may be detected along the cardinal margin from within 20 mm. of the beak to about 10 mm. beyond the point where the cardinal margin curves downward into the posterior margin of the shell. These plications form angles of about 70 degrees with the cardinal margin, and the longest, posteriorly, scarcely extend more than 5 mm. from the cardinal outline. Along the basal margin, these plications number about 3 in a length of 5 mm.

Locality. At the power house, about a mile southwest of the of Salmon River Falls, New York; in the upper areanaceous part the fossiliferous Lorraine.

Essentially the same form occurs in the Lorraine at Gorrel Point, two miles northeast of the village of Gore Bay, on Manitoulin Island, in Lake Huron. Fig. 16, on plate II, represents

one of these specimens, collected in 1911, by Aug. F. Foerste. The angle between the cardinal and basal margins is nearer 15 degrees, and the number of transverse plications along the lower half of the shell is nearer 4 or 5 in a length of 5 mm. These differences lie easily within the range of variation of this species. The specimen is numbered 8416 and is preserved in the Victoria Memorial Museum at Ottawa, Canada.

Whiteavesia pholadiformis was described by Hall from the Little Bay des Noquets, on the western side of Lake Michigan, in the *Report on the Geology of the Lake Superior Land District*, 1851, p. 213, and several figures were presented.

Among four specimens from the type locality, and belonging to the type series, No. 1365, but not figured by Hall, it is possible to distinguish two forms. Two of the specimens are quite elongate; one of these preserves the posterior outline but the part anterior to the beak is lacking; the other presents the anterior outline but not the posterior outline of the shell. The shell was of moderate height anteriorly, and the beak is rather distant from the anterior margin. The general outlines of these shells probably closely resembled that of Fig. 16 on plate II of the present publication. The other two specimens from the type locality evidently were higher and more broadly rounded anteriorly, and, judging from one of them, a so-called exterior-interior impression, also shorter. The transverse plications below the umbonal ridge are well developed in both forms, but the post-umbonal plications are only moderately developed, as in Fig. 16 on plate II, and not as in the form here called *divaricata*. The more elongate forms, resembling our Fig. 16, are regarded as the typical forms of *pholadiformis*. Figure 4 on plate V is one of Hall's types.

Forms unquestionably belonging to the *Whiteavesia pholadiformis* group, and usually identified with that species, occur also in the Lorraine of the province of Quebec. They occur associated with *Strophomena fluctuosa* about a mile west of Vars, a short distance south of the railroad. They also occur in the upper part of the Lorraine along the road, south of the railroad station at St. Hilaire. Along the Nicolet River, southwest of Ste. Monique, it occurs in the Richmond strata, 97, 110, and 120 feet above the lowest horizon containing *Strophomena planumbona*. It is found here also loose at 136, 220, and 430 feet below this *Strophomena planumbona* horizon, evidently in strata belonging to the upper

part of the Lorraine section, as here interpreted. It will be necessary to collect the specimens in order to assign them to their proper species, now that the presence of several species of this type is suspected.

It is scarcely necessary to state that the group of species typified by *Modiolopsis pholadiformis* does not belong to the genus *Whiteavesia,* as typified by *Whiteavesia cincinnatiensis,* Hall and Whitfield The striations of the latter are narrow and more or less radial, while the plications of the *Modiolopsis pholadiformis* group, along the basal margin, are broad and more or less transverse to the longitudinal axis of the shell, and posteriorly are more or less divergent from the umbonal ridge. For the latter the designation *Pholadomorpha* is here proposed, with *Modiolopsis pholadiformis* as the type.

16. Pholadomorpha pholadiformis—divaricata

(*Plate II, Fig. 14*)

Basal margin forming an angle of about 18 degrees with the cardinal margin; this results in a remarkably narrow outline anteriorly, which may be due in part to compression. Posterior margin very oblique, rounding gradually into the cardinal margin, and much more rapidly into the basal outline. Shell concentrically striated, but the conspicuous ornamentation consists of the low, broad, transverse plications characteristic of the species. These plications cover the lower slope of the shell, from the basal margin to the crest of the umbonal ridge, from the lower posterior angle to the anterior muscular area. The shell as a whole appears to have been shorter, and more convex; posteriorly the plications are much more oblique to the basal margin, especially toward the umbonal ridge which they approach here with a strong forward curve; toward the middle of the shell this forward curvature becomes less pronounced, and near the beaks the plications are almost vertical. Along the cardinal margin the low transverse plications are nearly vertical for a distance of about 2 mm., posteriorly, and then curve rapidly forward on approaching the umbonal ridge. Even along the upper part of the posterior margin, these low transverse plications curve first obliquely downward and then much more strongly forward on approaching the

cardinal ridge. Even the lower part of the posterior termination of the shell, above the umbonal ridge, is occupied by oblique plications. Transverse plications vary in number from 10 in a length of 10 mm. near the anterior part of the shell to 6 in the same length posteriorly. Length 66 mm., height posteriorly 31 mm., height at beak 20 mm., possibly shortened here by compression. Anterior margin extending 10 mm. anterior to the beak, convexity of the single valve about 7 mm.

Locality. Riviere des Hurons, near St. Jean Baptiste; collected October 1872 by Thomas Curry; forming specimen No. 2071, Paleontological Collections, Geological Survey of Canada, Victoria Memorial Museum, Ottawa, Canada.

The chief characteristics of the form here described are its shorter length, its greater convexity, and the more pronounced forward curvature of the low transverse plications. If these characteristics do not prove fairly constant, when numerous specimens from the same locality are collected, this form has no standing whatever, even as a variety.

The chief reason for describing the preceding specimen is the fact that this gives an appropriate opportunity to discuss the form described by Hall and Whitfield as *Sedgwickia? divaricata.* Although the type of this species should occur in the U. P. James collection, at Chicago University, it is unknown there. It was found in the shales of the Richmond group at Blanchester, Ohio. A mile northwest of Blanchester, where the north and south road crosses Second Creek, the lowest exposures belong to the lower *Hebertella insculpta* horizon, at the base of the Blanchester division of the Waynesville, but there is good collecting from here westward down the stream. Knowing this area very well, I am of the opinion that if ever the type of *Sedgwickia divaricata* is found it will prove to be a young specimen belonging to the *Whiteavesia pholadiformis* group. In young specimens of this species the basal margin is convex, and the umbonal ridge is fairly angular. Moreover, the concentric markings sometimes are fairly conspicuous on the cardinal slopes, and would be especially conspicuous on specimens in which these concentric markings were conspicuous below the umbonal ridge. Judging from the figure of *Sedgwickia divaricata* published in vol. ii of the *Palaeontology of Ohio,* the type specimen presented the low broad plications curving from the posterior margin of the shell obliquely forward

toward the umbonal ridge, as well as the concentric markings which sometimes are strongly developed here I regard the drawing of this form in the *Ohio Palaeontology* as misinterpreted and would not be surprised to learn that the details had been too strongly accentuated.

17. **Pholadomorpha chambliensis,** sp. nov.

(Plate I, Fig. 8)

Shell transversely oblong, the cardinal and basal margins diverging scarcely 10 degrees. The anterior margin is more broadly rounded and the posterior margin is less oblique than in typical Modiolopsis pholadiformis. The low transverse plications can be detected only on the posterior half of the shell, on the slope beneath the umbonal ridge, but they may be more distinctly indicated in other individuals. Umbonal ridge angulate along its upper outline for a distance of about 15 mm. from the beak, rounding rapidly posteriorly, merging into the general convexity of the shell.

Length 68 mm., height posteriorly 28 mm., height at beak 24 mm., extension of shell anterior to beak about 12 mm., convexity of the single valve about 3 mm.

Locality. Apparently from Chambly, from a siliceous limestone containing Byssonychia radiata, Rafinesquina alternata, and apparently also Catazyga headi. Specimen No. 2069, Geological Survey of Canada, in the Victoria Memorial Museum, Ottawa, Canada.

18. **Modiolopsis modiolaris,** Conrad

(Plate III, Fig. 1; Plate V, Figs. 1 A, B, C, 2 A, B, C)

In the *Second Annual Report of the New York Geological Survey*, 1838, Conrad described this species as follows:

> Shell ovate oblong, compressed; surface with coarse concentric lines, obsolete on the posterior side; posterior extremity obliquely truncated. Length, nearly 3 inches. *Locality*, Pulaski, Oswego county, with the preceding (*Cymatonota pholadis*).

The writer has recently collected *Modiolopsis modiolaris* in the same slab with Cymatonota pholadis, a short distance down

stream from the railroad bridge, about a mile east of Pulaski, and this is regarded as the type locality for both species.

In the *Paleontology of New York*, vol. I, 1847, on plate 81, Hall presents various figures of *Modiolopsis modiolaris*. Of these, Figs. 1*a*, *b*, represent specimens collected at Rome, while 1*c*, *d*, and *e* were drawn from specimens secured at the type locality, at Pulaski. Regarding Fig. 1*a*, Hall states: "This is one of the most perfect forms, and the one to which Mr. Conrad applied the name *modiolaris*." In one respect his published figure, however, differs from the specimens collected at the type locality: the angle between the cardinal and basal margins is greater. This is shown by the following table, giving the measurements for three specimens collected at Pulaski, one from half a mile east of Worthville (plate III, Fig. I), and for Fig. 1*a*, left valve, as published by Hall on plate 81 of the publication cited. (See Figs. 1, 2, on Plate V.) Measurements are given in millimeters.

LOCALITY	GREATEST LENGTH	POSTERIOR HEIGHT	HEIGHT AT BEAK	ANTERIOR MARGIN FROM BEAK	CONVEXITY OF SINGLE VALVE	ANGLE BETWEEN CARDINAL AND BASAL MARGINS	BETWEEN CARDINAL AND POSTERIOR MARGINS
Pulaski.......	57.0	26.0	20.0	10.5	4	11°	44°
Pulaski.......	59.0	27.0	20.0	10.0	4	11°	38°
Pulaski.......	63.5	30.5	25.0	12.0	4	10°	42°
Worthville....	70.0	32.0	23.5	10.0	4	12°	39°
Fig. 1*a*, Pl. 81.	69.0	33.0	22.0	11.0		19°	42°

Shell obliquely oblong. The cardinal margin posterior to the beak nearly straight, rounding gradually into the oblique posterior margin. Anterior to the beak, the cardinal margin is deflected downward, and then rounds into the strongly curved anterior margin of the shell. Basal margin straight along that part of the shell which lies directly opposite the straight cardinal margin; rising gradually toward the curved anterior margin, and more rapidly toward the posterior margin, which is most curved at the posterior extremity of the umbonal ridge. Umbonal ridge most strongly defined on the cardinal side and within about 10 or 15 mm. from the beak, almost disappearing into the general convexity of the shell posteriorly. Mesial sinus practically obsolete, although occasional specimens show a very faint indication of the same accompanied by a scarcely perceptible concavity of the

basal outline. General convexity of the shell small. Concentric striations best defined anteriorly, along that part of the shell which is anterior to the oblique umbonal ridge. Anterior adductor depressions large and distinctly defined, although usually very shallow, owing to the thinness of the shell. The interior of one of the valves is faintly striated posteriorly, below the umbonal ridge, in a direction parallel to a line drawn from the posterior termination of the umbonal ridge to a point half way between the beak and the upper anterior margin of the shell.

Locality. Pulaski, a short distance down stream from the railroad bridge, about a mile east of the town; also in the Trinucleus horizon, a short distance farther down stream; and still farther down stream, below the dam, at the southwestern margin of the town. Within the village of Barnes Corners; also a mile southward. At Worthville, and also half a mile eastward. At the school at the head of the road from Turin westward through the Gulf and then southwestward up the hill. Half a mile down stream from the Salmon River Falls, a short distance below the level of the base of the falls.

19. **Modiolopsis concentrica,** Hall and Whitfield

Modiolopsis concentrica was described from the Waynesville beds near Waynesville, Ohio.

In Canada, specimens occur which unquestionably belong to the same group and are closely related, but the latter may not prove identical. One of these specimens, collected at Chambly, presents the following characteristics. The curvature of the shell along the hinge-line passes gradually into that of the strongly deflected posterior outline, as in *Modiolopsis concentrica,* but the concentric plications along the post-umbonal parts of the shell are far less conspicuous, the umbonal ridge is flatter, the area which should be occupied by a mesial sinus is scarcely concave, and the basal margin of the shell is scarcely concave.

Locality. Specimen numbered 1545 and labelled as coming from Chambly. Preserved in the Victoria Memorial Museum, at Ottawa, by the Geological Survey of Canada.

Modiolopsis concentrica does not belong to the group of *Modiolopsis modiolaris.* An examination of the types, in the Museum at Albany, New York, indicates that *Modiolopsis modiolaris*

belongs to the group of shells having a comparatively straight hinge-line posterior to the beak, and a moderately convex or nearly straight, instead of concave basal margin; there is no mesial sulcus; and the anterior margin of the shell extends conspicuously in front of the beaks.

20. **Modiolopsis postplicata,** sp. nov.

(*Plate I, Fig. 4*)

Hinge-line arcuate posterior to the beak, gently declining toward the posterior extremity and gradually rounding into the oblique posterior margin; umbonal ridge broad and low, rounded rather than angulate; mesial sulcus shallow, forming an undefined depression across the valves from the beak toward a point slightly anterior to the middle of the basal margin, where the latter is slightly concave; cardinal or post-umbonal slope marked by regular, even, concentric plications becoming obsolete toward the crest of the umbonal ridge; these plications mark successive growth stages of the posterior margin of the shell; there are about 5 plications in a length of 5 mm., increasing to 6 in the same length posteriorly; within 10 mm. from the posterior margin, fine concentric striae are seen in addition to the plications. Concentric striations are present also on the areas below the umbonal ridge; these striations are faint posteriorly, but become sharply defined anteriorly, where they also are more crowded. The valves probably were very thin, since not only the position of the anterior muscular scar, but also that of the anterior part of the pallial line, for a distance of 10 mm., is distinctly indicated. Both the cardinal and the basal margins are curved, the curvature of these margins being approximately equal, the margins being subparallel.

Length 58 mm., height 18 mm., height at beak 16 mm., extension of shell anterior to the beak about 10 mm., convexity of the single valve about 4 mm.

Locality. Type, associated in same rock fragment with *Lophospira beatrice* and *Pterinea demissa;* collected on the Riviere des Hurons, near St. Jean Baptiste, October 1872, by Thomas Curry; preserved in the Paleontological collections of the Geological Survey of Canada, in the Victoria Memorial Museum, Ottawa, Canada. No. 8424.

A second specimen, numbered 2086, is labelled as coming from the Plunk River, at Chambly, Quebec. Although only about 42 mm. in length, it shows the post-umbonal plications very well.

This species is long and narrow, and has the subparallel cardinal and basal margins as in *Orthodesma*, especially that group of species represented by *Orthodesma curvatum*. However, the post-umbonal plications are much more suggestive of some species of *Modiolopsis* belonging to the *Modiolopsis concentrica* group. This form of ornamentation is unknown in *Orthodesma* but is frequent in *Modiolopsis;* for instance in *Modiolopsis arguta* and *Modiolopsis obsoleta*. Compared with these shells, however, the height of the shell is less enlarged posteriorly. If we have not misinterpreted this species it combines the characteristics of two genera, usually easily differentiated.

21. **Orthodesma approximatum,** sp. nov.

(*Plate I, Fig. 5*)

Shell possibly closely related to *Modiolopsis postplicata*, but differing in the absence of conspicuous plications on the post-umbonal slopes. If this species is an *Orthodesma* it belongs to the *Orthodesma curvatum* group. The cardinal margin is slightly curved posteriorly. Excepting near the beak, the umbonal ridge is distinguished only faintly from the general convexity of the shell, and the mesial sulcus is nearly obsolete. The surface is marked by faint concentric striations and wrinkles which are most distinct below and anterior to the beak. Along the post-umbonal slopes, when held in a very oblique light, very faint concentric wrinkles, about 8 or 9 in a length of 5 mm., may be seen, but it is difficult to imagine these as suggesting identity of the form here described as *Orthodesma approximata* with *Modiolopsis postplicata*. The position of the anterior muscular scar and of the adjacent part of the pallial line, for a distance of about 10 mm., is distinctly indicated. The general appearance of the shell is smoothish. From the cardinal side of the umbonal ridge, near the beak, a low angulation extends backward, gradually deviating from the cardinal margin, until at a distance of 30 mm. from the beak it is fully 2.5 mm. from this margin. Above this angulation the surface along the cardinal margin is concave, as though the

cardinal parts of the two valves had been more or less appressed posteriorly.

Length about 50 mm., height 19 mm., height at beak 17 mm., extension of shell anterior to the beak 8 or 9 mm., convexity of a single valve about 5 mm.

Type. From the Richelieu River at Chambly, collected in 1881 by A. H. Foord. Both valves are present but only the right valve is figured. Associated with *Glossograptus quadrimucronatus-approximatus*) in the same rock fragment. Preserved in the Victoria Memorial Museum, by the Canadian Geological Survey at Ottawa, Canada. No. 8425.

22. **Orthodesma nasutum,** Conrad

(*Plate III, Figs. 5 A, B; Plate V, Figs. 3, A, B, C*)

Orthodesma nasutum was described by Conrad from the vicinity of Rome, New York. It occurs, according to Hall, in the arenaceous strata of the higher part of the group, and has not been seen in the underlying softer shales. The figure presented by Hall in the *Paleontology of New York*, vol. I, on plate 81, is from a defective specimen. The original of this figure is preserved in the State Museum at Albany, and is labelled as coming from Lorraine, in Jefferson county. The upper margin anterior to the beak is missing but sufficient is present to indicate that this upper margin was at a distinctly lower level than that part of the cardinal margin which is posterior to the beak. See Fig. 3, on plate V.

According to my own observations *Orthodesma nasutum* is a fairly common species in the upper part of the Lorraine section of New York. It occurs at Bennett's bridge, about a mile down the river from the Salmon River Falls. Here it is associated with *Rafinesquina mucronata*, ordinary flat *Rafinesquina alternata, Whiteavesia pholadiformis, Byssonychia radiata, Lyrodesma poststriatum,* a species closely related to *Ischyrodonta unionoides*, and *Archinacella pulaskiensis*. The overlying layers, half a mile nearer the falls, contain also *Pholidops subtruncatus* but rounded anteriorly as in *Pholidops cincinnatiensis, Catazyga erratica, Modiolopsis modiolaris, Clidophorus planulatus,* and *Cyrtolites ornatus*.

Specimens of *Orthodesma nasutum* occur also about a mile

south of Barnes Corners, associated with *Modiolopsis modiolaris* and *Catazyga erratica*, and at Worthville, but the best specimens were collected about two and a half miles east of Worthville (plate III, Fig. 5 A. B.), in association with *Ischyrodonta* cf. *unionoides*, and it is the first mentioned specimen which forms the basis of the following description. The horizon of the species is distinctly above that exposed at the village of Lorraine, and also above that exposed east of Pulaski. No specimens of *Plectambonites* or *Dalmanella*, so common at the lower horizons, have been noticed here. Although further investigations may result in the finding of these genera also at higher horizons in the Lorraine, they are known to be at least very rare there. In the preceding lists of fossils, the species mentioned as related to *Ischyrodonta unionoides* is the *Ischyrodonta curta* of Conrad.

Species belonging to the group of *Orthodesma curvatum*, Hall and Whitfield, from the Waynesville division of the Richmond, but differing in many particulars. In a specimen about 44 mm. in length, the cardinal margin is only slightly convex for a distance of about 20 mm. posterior to the beak; then it curves more rapidly downward into the very oblique posterior margin. The latter forms an angle of about 35 to 40 degrees with the longitudinal diameter of the shell. Greatest curvature at the lower part of the posterior margin, where it rounds strongly into the only slightly convex basal margin. Near the beak this margin curves upward into the strongly rounded anterior margin. The striking feature of the shell, that which suggested the name *nasutum*, is the distinct dropping of the cardinal margin anterior to the beak. Although this is exaggerated in Hall's figure of *Orthodesma nasutum*, it is nevertheless real. About 8 mm. anterior to the beak this lowering of the upper margin of the shell amounts to fully 3 mm. The umbonal ridge is only weakly defined, and rounds into the general convexity of the shell; the area of greatest convexity lies rather near the cardinal margin posterior to the beak and then curves gradually downward toward the lower part of the posterior margin. Anterior to the beak, the shell is depressed, adding to the nasute appearance of the shell. There is no indication of a mesial sinus. Surface weakly marked by concentric striations, which are most distinct anteriorly, and fairly distinct along the basal margin. Greatest height at midlength, about 15.5 mm.; diminishing to 13 mm. at the beak, owing to the downward curvature of the

cardinal the outline at the beak. Anterior margin of shell fully 12 mm. in front of the beak. Convexity, nearly 4 mm.

23. **Orthodesma pulaskiensis,** sp. nov.

(*Plate III, Fig. 6*)

Basal and cardinal margins subparallel. In a shell having a length of 49 mm. the height at the beak is 13.5, and posteriorly it increases to 15.5 mm. The anterior extremity extends about 10 mm. beyond the beak, and is incurved below the level of the cardinal outline. In the type specimen, a rather angular umbonal ridge extends from the beak obliquely backward, becoming considerably less distinct along the posterior fifth of the shell. This angular umbonal ridge is the most characteristic feature of the type specimen but may not be equally well developed in other specimens belonging to this species. Below this umbonal ridge, and anteriorly, the shell is marked by distinct concentric striae. Above this ridge, on the post-umbonal slope, the concentric striae are far less distinct. The anterior muscular scar is fairly large, and distinctly outlined, but not deeply impressed. From its lower posterior margin, a series of short vertical lines extends obliquely backward, and has some connection with the pallial line. The cardinal margin slopes gradually downward, rounding into the posterior margin, which is most strongly rounded along the lower third of its outline.

Locality. Immediately below the railroad bridge, 1 mile east of Pulaski, New York(plate III. Fig. 6).

The relationship of this form to the *Modiolopsis anodontoides* of Hall (Pal. N.Y. vol. I, pl. 82, Fig. 3a) remains to be determined, but the latter appears to be shorter, with a straighter umbonal ridge, which is more divergent from the cardinal line near the beak. According to a label by Hall, Fig. 3b, pl. 82, the original of *Cypricardites sinuata,* Emmons, "proves to be the young of *Cimitaria recurva,* Hamilton Group."

A form with somewhat similar outline, but with the beak nearer the anterior margin, was found at a considerably higher horizon, in the fossiliferous sandstones, at the cross-roads, one mile south of Barnes Corners (plate III, Fig. 10). The umbonal ridge is not angular, and is distinct only near the beak. In consequence the slopes below the umbonal ridge, toward the basal

margin, and above this ridge, toward the cardinal outline, are not flattened, but have a more evenly convex appearance. The general aspect is that of a *Cymatonota* but there are no oblique wrinkles along the hinge-line.

If *Cymatonota parallela*, Hall, (*Paleontology of New York*, vol. i, plate 82, Fig. 7*c*) did not show the oblique folds along the cardinal line, which are characteristic of *Cymatonota*, the Barnes Corners species might have been compared with that form, although the latter is figured as somewhat shorter. It is evident from the descriptive text that Hall included both forms with and without an oblique carina, and both with and without oblique folds on the cardinal margin in his species, but he placed special emphasis on the presence of the oblique folds along the hinge-line, and only forms possessing these folds can be regarded as typical.

The Barnes Corners specimen resembles most closely the *Orthodesma parallelum*, from Rome, used for Fig. 712, on page 511 of Dana's Manual of Geology, which may be a *Cymatonota*.

24. **Orthodesma prolatum,** sp. nov.

(*Plate I, Fig. 15*)

Hinge-line posterior to the beak apparently straight, meeting the upper part of the oblique posterior margin at an angle of about 120 degrees. Umbonal ridge rather angular, especially toward the beak. The postumbonal slope, between the umbonal ridge and the cardinal margin, is flattened, or, rather, it consists of two flattened areas meeting each other at an angle of about 170 degrees. At the posterior extremity of the shell, this second line of angulation is about 5 or 6 mm. distant from the crest of the umbonal ridge and 4 mm. distant from the cardinal margin. It is not known whether this second line of angulation is a constant characteristic of the species, but, in the single individual at hand, it is noticed that the concentric striae ornamenting the shell become conspicuously more prominent, broader, and more regular, between this second line of angulation and the cardinal margin, than elsewhere on the shell. Of these prominent striae along the cardinal margin there are about 8 in a length of 5 mm. measured transversely to the striae. Elsewhere on the shell the concentric striae are finer and closer, and are accompanied by obscure con-

centric undulations of growth. Although the anterior margin of the shell is not preserved, enough of the shell anterior to the beak is seen to indicate that the concentric striae and obscure undulations are not gathered up anteriorly into a series of strong concentric folds, as in *Rhytimya,* nor are there any obliquely radiating series of granules between the umbonal ridge and the basal margin as in characteristic species of that genus, to which the present form evidently is not related.

Cardinal and basal margins subparallel posterior to the beak, the height being 11.5 mm. at the beak and 13 mm. at the posterior end. The anterior end of the type specimen is defective but enough remains to indicate that it projected about 11 mm. anterior to the beak. Length 38 mm., convexity of single valve about 4 mm.

Locality. Type, associated in the same slab with numerous fragments of a *Strophomena* resembling *Strophomena hecuba,* one good specimen of *Rafinesquina alternata,* one of *Pterinea demissa,* and apparently a fragment of *Catazyga headi;* collected on the beach below Becancour river, and therefore presumably along the St. Lawrence river, October 3, 1852, by James Richardson; forming specimen No. 2144, Palaeontological Collections, Geological Survey of Canada, Victoria Memorial Museum, Ottawa, Canada.

In the subparallel outline of the shell and in the angularity of the umbonal ridge this species resembles *Orthodesma,* but there is no evidence of a conspicuous anterior muscular scar; however only the exterior of the shell is presented. The general aspect of the shell is somewhat like that of *Cymatonota,* but there is no indication of oblique undulations along the cardinal margin, and the umbonal ridge is more angular. Compared with *Modiolopsis postplicata,* both the cardinal and basal margins are straighter, the umbonal ridge is more angular, there is no trace of a mesial sulcus, nor of an anterior muscular area, and the prominent oblique striae along the hinge-line are more numerous.

25. **Cymatonota lenior,** sp. nov.

(*Plate I, Fig. 9*)

Shell with the general aspect of a Cymatonota but without the oblique wrinkles along the hinge-line, posterior to the beak. The

hinge-line is straight for a distance of at least 37 mm. from the beak, and possibly farther, rounding into the posterior margin of the shell. The latter is rounded. The basal margin is straight as far as a point directly beneath the beak, thence it curves upward toward the anterior margin which is most convex near its junction with the anterior part of the cardinal outline of the shell. The shell enlarges only moderately posteriorly, the basal margin being subparallel to the hinge-line. Umbonal ridge weakly defined even within 15 mm. of the beak, and rounding posteriorly into the general convexity of the shell. Concentric striae most distinct along the anterior parts of the shell, and also along the base; less conspicuous along the posterior border; and rather indistinct along the umbonal ridge and over most of the post-umbonal slope.

Length 70 or 71 mm., greatest height posteriorly 22 mm., height at beak 16 mm., extension of shell anterior to beak estimated at 12 mm., convexity of the single valve about 4 mm.

Locality. Type, collected on the Riviere des Hurons, near St. Jean Baptiste, October, 1872, by Thomas Curry. Preserved in the Victoria Memorial Museum, by the Geological Survey of Canada, at Ottawa, Canada. No. 8422.

26. **Cymatonota pholadis,** Conrad

(*Plate III, Fig. 7*)

In the *Second Annual Report of the New York Geological Survey,* in 1838, Conrad described this species as follows:

> Shell profoundly elongated, ventricose; dorsal and basal margins parallel; posterior sides rugose, or with short undulations near the dorsal margin. Length, $1\frac{3}{4}$ inches.

In describing the next species(*Modiolopsis modiolaris*), he gives the locality for that species as "Pulaski, Oswego county, with the preceding." From this it is evident that the type locality for *Cymatonota pholadis* is Pulaski.

In the *Paleöntology of New York,* vol. i, on plate 82, Fig. 6 was published by Hall from a drawing prepared by Conrad, and therefore authentic. Hall states that *Cymatonota pholadis* resembles a new species, *Cymatonota parallela,* occurring "in the soft shaly portions of the group at Pulaski, Loraine, and other places.

I have obtained casts of the same from the ferruginous sandstones in the higher part of the group." The types of the latter are illustrated by Figs. 7*b* and 7*c* on plate 82, and were obtained from Pulaski, in other words from the same locality as the type of Conrad's species *Cymatonota pholadis*. Of the two illustrations of *Cymatonota parallela*, only 7*c* is serviceable in the identification of this species, and this is described in the descriptive matter accompanying the plate as "the left valve, preserving the shell, which is finely striated concentrically, and shows the folds upon the cardinal line." In the text the species is described as having "a few oblique strong wrinkles along the dorsal margin." No consideration need be given in this connection to figures 7*a* and 7*d* on the same plate since these illustrate a species of *Orthodesma* obtained at Cincinnati, Ohio, erroneously referred to the same species. The original of Fig. 7*c* has the relative height and length indicated by the figure, except that the lower part of the posterior margin should be prolonged. The original of Fig. 7*b* is a much better specimen than the published drawing suggests.

In view of the fact that *Cymatonota pholadis* and *Cymatonota parallela* both came from the same type locality, and that specimens referred to the latter are common while no other specimen having the exact dimensions of *Cymatonota pholadis* have ever been found in New York subsequent to the original description, it becomes pertinent to inquire if *Cymatonota pholadis* may not have been an aberrent specimen of *Cymatonota parallela*. In the absence of the type of *Cymatonota pholadis*, which had been lost apparently even before Hall wrote his work, this question can not be answered with absolute certainty, but it is extremely probably that the type of this species was merely a compressed specimen of the species later described by Hall as *Orthonota* (=*Cymatonota*) *parallela*.

Specimens of *Cymatonota* have been collected a short distance below the railroad bridge, about a mile east of Pulaski, in the same rock slab with *Modiolopsis modiolaris*, and *Ischyrodonta unionoides*, and they continue to be found for several hundred yards westward, where they occur associated with *Trinucleus*. A specimen 34 mm. in length had a height of 10.5 mm. near the posterior end, and of 9 to 9.3 mm. at the beak; the anterior margin extends between 6 and 7 mm. anterior to the beak, and the straight cardinal margin reaches 23 or 24 mm. posterior to the

beak. The height of the shell, therefore, increases slightly posteriorly, as might be expected, and the ratio of maximum height to length is about as 3 to 10. The posterior margin is not evenly rounded but is distinctly oblique, making an angle of about 40 degrees with the cardinal margin, while the nearest oblique wrinkles make angles of about 50 degrees. Opposite the posterior termination of the umbonal ridge the rounded outline is more nearly vertical. The greatest curvature is where the posterior outline curves into the basal margin. Umbonal ridge distinctly defined on the cardinal side near the beak, becoming rounded about 15 mm. from the beak and merging into the general convexity of the shell posteriorly. Concentric striations most distinct along the anterior third of the shell, becoming broader and sharply defined posteriorly. Along the umbonal ridge and posterior cardinal slopes, the concentric striae usually are faint. Oblique wrinkles most strongly defined within 13 to 15 mm. from the beak, becoming lower and broader posteriorly.

Specimens of *Cymatonota* of this type have been found, associated with *Trinucleus*, also near the head of the Gulf along the road leading southwest out of the gully toward the school house, about two miles west of Turin (plate III, Fig. 7).

Specimens possessing these characteristics occur at Chambly, along the Richelieu River, in the province of Quebec. A specimen, labelled Chambly Point. R9., is preserved by the Geological Survey of Canada in the Victoria Memorial Museum, at Ottawa, Canada. The handwriting on the label is the same as that on the type of *Whitella complanata,* and the specimen probably was collected by James Richardson. It is illustrated by Fig. 14, on plate I of this *Bulletin,* and is numbered 2085. The following description may be added.

Basal margin straight, nearly parallel to the cardinal margin. Posterior margin oblique. Concentric striae below and anterior to the umbonal ridge. This ridge is distinct anteriorly but becomes more rounded posteriorly. Oblique folds or undulations along the hinge-line conspicuous.

Specimens having the same characteristic occur at the Chambly horizon in the section along the Nicolet River, southwest of Ste. Monique. Here they are associated in the same rock fragments with *Rafinesquina mucronata, Catazyga headi, Pterinea demissa,* and *Lyrodesma poststriatum.* At this horizon *Proetus* also is com-

mon. The range of *Proetus* here is from 533 to 1002 feet below the lowest horizon at which *Strophomena planumbona* and *Rhynchotrema perlamellosa* occur. The specimens of *Cymatonota* just mentioned occur in the upper part of this zone, between 533 and 566 feet below the lowest *Strophomena planumbona* zone. Similar specimens of *Cymatonota* occur also 1699 feet below the lowest *Strophomena planumbona* horizon, in association with *Trinucleus* and *Triarthrus,* and some make their appearance as far up as 50 and 105 feet below the lowest *Strophomena planumbona* horizon.

Cymatonota of the same type occurs also at St. Hilaire; and about 12 miles east of Ottawa, at a road corner reached by going from Vars station three-quarters of a mile westward along the railroad, and then a mile northwestward along the country road.

Among the species described by Ulrich, *Cymatonota pholadis,* as here described, most closely resembles *Cymatonota recta,* from the Fairmount member of the Maysville division of the Cincinnatian, at Cincinnati, Ohio. A full description of *Cymatonota recta,* with notes on *Cymatonota pholadis* and *C. parallela,* is given in the *Geology of Ohio,* vol. vii, p. 662.

27. **Modiolodon poststriatus,** sp. nov.

(*Plate I, Fig. 7*)

Cardinal margin slightly convex, joining the posterior outline, rather abruptly, at an angle of about 65 or 70 degrees. The basal margin diverges from the cardinal margin at an angle of about 15 degrees, rounding rapidly into the posterior margin and into the anterior outline. The umbonal ridge is rather poorly defined in the specimen at hand. The anterior muscular area is strongly defined. Posteriorly, above the umbonal ridge, the shell is strongly marked by striae which are parallel to the posterior margin; of these striae there are about 9 in a length of 5 mm. Elsewhere on the shell there are only faint indications of concentric striae.

Length 35 mm., height posteriorly 20 mm., height at beak 14 mm., extension of shell anterior to beak about 3 or 4 mm.

Locality. One mile west of Vars, along the railroad, and then half a mile northward along the road, associated in the same slab with *Catazyga headi;* collected in 1912 by Aug. F. Foerste. Pre-

served in the Victoria Memorial Museum, at Ottawa, Canada, by the Geological Survey of Canada. No. 8428.

This species probably is closely related to *Modiolodon truncatus*, Hall, and *Modiolodon subovalis*, Ulrich. At least it presents a similar outline, but there is no evidence of the presence of teeth near the beak.

28. **Psiloconcha subovalis,** Ulrich

(*Plate II, Figs. 15 A, B*)

The specimens here described resemble closely the specimen of *Psiloconcha subovalis* figured by Ulrich from the Maysville division of the Cincinnatian section at Morrow, Ohio. The anterior margin is rather oblique as it rounds into the basal margin, and the hinge-line posterior to the beak is straight for about a distance of 21 mm. in a shell 35 mm. long and 17 mm. high, resulting in a rather high shell considering the group of species so far included in the genus. The convexity of the single valve is about 3 mm. Compared with the figures of *Psiloconcha subovalis* the beak is broader and more protuberant, the junction of the umbonal ridge with the cardinal slope is more angular along the distance from the beak halfway toward the posterior margin, the faint mesial depression or flattening is more distinct, and anteriorly the beak is defined more strongly by an oblique angulation almost as strong, although much shorter than the umbonal ridge; moreover, the anterior margin is more regularly rounded. At the beak the shell appears compressed, as though the shell had formerly been more inflated along the umbonal areas.

The specimens here figured were obtained along the Riviere des Hurons, near St. Jean Baptiste, October, 1872, by Thomas Curry, and are associated in the same block with Clidophorus praevolutus and a pygidium of Isotelus. Preserved by the Geological Survey of Canada in the Victoria Memorial Museum at Ottawa. No. 8408.

Shells indistinguishable from *Psiloconcha inornata*, Ulrich, occur half a mile south of the railroad station at St. Hilaire, in a ditch along the road; and a closely similar species occurs a mile and a half northwest of Vars, at a crossing of two country roads.

29. **Psiloconcha sinuata—borealis,** var. nov.

(*Plate II, Figs. 9 A, B, C*)

Specimen about 22 mm. in length, with the hinge-line straight for a distance of about 7 mm. posterior to the beak, and then deflected downward for a distance of about 8 mm. at an angle of about 165 degrees with the hinge-line, before curving rapidly into the rather narrowly rounded posterior margin. Umbonal ridge and mesial sulcus very oblique, and only moderately distinct, but at least much more distinct than in most species of this genus. The umbonal ridge is most distinct within about 5 mm. of the beak, and below this part of the ridge the shell is distinctly flattened, the flattening becoming more concave on following the mesial sulcus toward the basal margin. The latter is comparatively straight but in older specimens might easily become slightly concave. The chief difference between the form here figured and typical *Psiloconcha sinuata*, Ulrich, consists in the anterior outline, which is less quadrate, the hinge-line anterior to the beak being less in line with that posterior to the same, but rather deflected downward as in *Psiloconcha inornata*, Ulrich. Convexity of the single valve fully 2 mm.

As the type of this form has been selected No. 8411 (plate II, Fig. 9*B*) from a group labelled as coming from the Riviere des Hurons and collected October, 1872, by Thomas Curry. Although no separate label was attached to this type specimen it is regarded as unquestionably coming from the same locality as the remainder. It is associated in the same slab with *Clidophorus praevolutus* Fig. 6, plate I. On plate II, Fig. 9*A*, represents the two opened valves of another specimen from the same locality; and bears the number 2087. Fig. 9*C* represents a similar specimen collected by Aug. F. Foerste along the Nicolet River, southwest of Ste. Monique. It occurred somewhere beneath the 80-foot level below the lowest horizon containing *Strophomena planumbona,* at the high river bluff south of the Lower Richmond exposures, and is numbered 8412. In my notes I called it *Psiloconcha sinuata-minima*.

All of the specimens are preserved by the Geological Survey of Canada, in the Victoria Memorial Museum, at Ottawa.

Psiloconcha inornata, Ulrich, is a distinctly flatter shell, with a scarcely ceptibleper umbonal ridge except in the immediate

vicinity of the beak, and with no indication of the mesial sinus. The hinge-line is gently and almost evenly curved downward posteriorly. A specimen of this type, associated with *Catazyga headi, and Pholidops subtruncatus*, occurs among a group of specimens labelled as coming from Chambly. No. 8431.

30. **Cyrtodonta clochensis,** sp. nov.

(*Plate II, Figs. 6 A, B*)

Shell of medium size, obliquely ovate, widest posteriorly; height and length in the ratio of 17 or 18 mm. to 25 mm. with a convexity of 5 mm. in the type specimens, increasing to fully 6 mm. for the single valve in others of the same size. Beaks rather prominent, the umbones rising distinctly above the hinge-line; umbonal ridge rounded, but made more prominent by the flattening of the valves anterior to this ridge. In some specimens this flattening is accentuated to a slightly concave curvature extending obliquely backward fromthe anterior half of the umbones. Surface marked by fine concentric striae. Anterior muscular scar fairly large and rotund. The interior cast here figured exposed the presence of two subequal cardinal teeth which are nearly parallel to the upper anterior margin of the valve; posteriorly there are casts of two long teeth which are subparallel to this margin of the valve.

In outline this shell bears a considerable resemblance to *Cyrtodonta janesvillensis*. It is evident from the growth lines that the lower margin of the specimen here represented by Fig. *6B*, on plate II, originally had the lower margin nearly straight for a distance farther to the rear than here figured, but the beaks and umbonal ridge appear to be much more prominent, and the greatest convexity of the anterior margin appears to be nearer the hinge-line.

Locality. In the lower red clay shales of the Lowville bed along the western shore of La Cloche peninsula, a few feet above the railroad level. Collected in 1912 by Aug. F. Foerste, and preserved in the Victoria Memorial Museum, at Ottawa, by the Geological Survey of Canada. Nos. 8410, 8410*a*.

31. **Ischyrodonta curta,** Conrad

(*Anadontopsis unionoides, Meek, Pal. Ohio, vol. I, pl. XII, Fig. 2*)

(*Plate III, Figs. 14 A, B*)

In the exposures at Bennett's bridge, a mile down stream from Salmon River Falls, a species is quite common which can not be distinguished from *Ischyrodonta unionoides*, from the Fairmount member of the Maysville division of the Cincinnatian. What must be called the basal margin is slightly less convex, so that the angle with the cardinal margin becomes more acute, and the curvature at the anterior margin correspondingly greater. Moreover, the cardinal margin posterior to the beak is straighter, for a distance about as far as the anterior margin extends forward from the beak; in consequence, the angle between the cardinal margin and the posterior is slightly more angular. The oblique lines being accentuated, the shell is slightly less rotund, but the differences are scarcely specific.

The species also occurs at lower horizons, being found within a hundred yards down stream from the railroad bridge, east of Pulaski. At the higher horizon, it occurs also two and a half miles east of Worthville. A similar form occurs two miles west of Worthville.

This shell is so common at some of the upper horizons in the Lorraine, that it could hardly have escaped the attention of the early investigators. It is identical with the *Cypricardites curta* of Conrad, described from a corresponding horizon. The following is the original description, published in the fifth annual volume of the New York Geological Survey, on p. 53, in 1841.

> Suborbicular, compressed; hinge margin elevated; posterior margin obtusely rounded. Localities. Near Rome, Oneida county, Richmond, Indiana.

It is the only shell at the Talcott and Comstock quarries, two miles south of Rome, which could be described as SUBORBICULAR. The specimen of *Ischyrodonta curta* figured by Hall (*Paleontology of New York*, vol. I, plate 81) from Grimsby, in Canada, is a very typical form of the species. Fig. 2*a*, on plate 82, however, which may be regarded as the type of Hall's species, *Modiolopsis curta*, is a small individual of *Pterinea demissa*,

from Lorraine, with most of the anterior ear and posterior wing missing. This *Pterinea* probably suggested part of Hall's description: "in specimens not compressed, there is an obtuse oblique carina, extending from the beak to the posterior margin above the base." Since Hall's type proves to be a *Pterinea demissa*, his species evidently has no standing. Figures 2*b* and 2*c* on plate 82 represent two more species included by him under the term *curta*.

32. **Whitella securiformis,** sp. nov.

(*Plate I, Fig. 1*)

Shell rotund quadrangular in outline. The greatest diameter from the hinge-line to the basal margin is 47 mm., while the greatest length is about 55 mm. The outline is strongly rounded both where it turns from the hinge-line posterior to the beak toward the posterior margin, and also from the latter toward the basal margin, but, in a general way, the hinge-line may be said to form an angle of about 110 degrees with the posterior margin, and the latter an angle of about 75 or 80 degrees with the basal margin. Anteriorly, the basal margin rounds evenly into the broadly convex anterior margin. In outline this shell most nearly resembles *Whitella subovata*, Ulrich, but the basal and posterior margins are somewhat straighter and hence the lower posterior part is more angular. The shell is only moderately convex, the convexity of the single valve being about 11 mm. The beak is broken off, but enough remains to indicate that the umbonal ridge was only slightly developed, the angularity between the umbonal parts and the cardinal slope being but poorly defined even in the immediate vicinity of the beak. In other individuals it may have been greater, but it is scarcely likely that in any specimens the strong angularity seen in the majority of the species of this genus, toward the beak, ever was present. The beak probably projected only about 3 mm. beyond the hinge-line. The shell is ornamented by concentric striae which are fainter toward the hinge-line.

Type. From Riviere des Hurons, collected by James Richardson. Listed in the general report on the *Geology of Canada* published in 1863, under the name *Modiolopsis securiformis*, and

preserved in the Paleontological collection, Canadian Geological Survey, Victoria Memorial Museum, Ottawa, Canada. No. 8420. This species was named, but not described or figured, by Billings.

33. **Whitella complanata,** sp. nov.

(*Plate I, Fig. 2*)

Shell originally probably very oblique, with a relatively short hinge-line and anterior margin, and a long basal margin, but at present strongly compressed toward the beak, decreasing the original convexity of the shell, especially along the umbonal areas, and somewhat obscuring the character of its original outline to the beak. Length of the shell along the umbonal ridge, from the beak to the lower posterior margin, 60 mm.; greatest length from front to rear, parallel to the basal margin, 58 mm.; diameter transverse to the latter measurement, 36 mm.; convexity of the single valve in its present compressed condition 10 mm., originally possibly 15 mm.; hinge-line posterior to the beak at least 20 mm., possibly 25 mm. in length. Umbonal ridge forming an angle of about 45 or 50 degrees with the hinge-line, as far as can be determined from the present condition of the specimen. It is quite evident that the umbonal ridge never was conspicuously developed, its convexity being only slightly greater than that of the remainder of the shell, and it never was angular, even near the beak. The beak apparently was broad and the anterior margin extended but moderately beyond the beak. The nearly straight basal margin rounds rather rapidly into the moderately convex posterior margin, the two forming, in a general way, an angle of about 60 degrees. It is evident from the growth lines that this angle becomes more acute with age, and that the length along the umbonal ridge increases more rapidly than any other dimension.

Type. Bearing two labels. One of these is: *Modiolopsis complanata,* Riviere des Hurons, Hudson River group, James Richardson; and the other: Richelieu River, Chambly v. 8. The two localities are by no means identical. In the *Geology of Canada* published in 1863, this species is listed from the Riviere des Hurons. Lithologically, the rock might come from either locality. On the rear of the type specimen, *Lyrodesma poststriatum* is present. The type, numbered 8421, is preserved in the Victoria Memorial Museum, Ottawa, Canada. It was named but not described or figured, by Billings.

The generic reference of this shell to *Whitella* must be regarded as provisional, until further specimens can be collected at the type locality. The absence of a strongly defined umbonal ridge, especially toward the beak, is noteworthy. There is a superficial resemblance to *Cuneamya.* However, there is no evidence of a well defined escutcheon of the form found in *Cuneamya*, nor of an anterior lunule. Moreover, there is no broad, undefined mesial sulcus.

34. **Whitella goniumbonata,** sp. nov.

(*Plate I, Fig. 3*)

Shell small, short, subrhomboidal. Beaks nearly terminal, enrolled toward the hinge-line so as to produce a concave anterior area 11 mm. long along the anterior margin, and 2 mm. in width on the single valve. Present convexity of the single valve about 5 mm. but the original form of the shell probably was more ventricose, producing a more prominent umbonal area and a greater width for the anterior concave area. Umbonal ridge, at its junction with the cardinal slope, angular, the angle being sharply defined from the beak for a distance of about 17 mm. toward the lower posterior angle of the shell, and then becoming more rounded. Concentric striae rather faintly defined.

The hinge area is not exposed in the specimen at hand. The generic determination is based upon the general appearance of the shell. It evidently belongs to the same group as *Whitella obliquata*, Ulrich, but the shell is relatively shorter with a less oblique posterior margin, and with a less oblique umbonal ridge.

Length 24 mm., length from the beak along the umbonal ridge to the lower posterior margin 25 mm.; height posteriorly 20 mm., height at the beak about 17 mm.; extension of the shell anterior to the beak about 2 mm.; convexity of the single valve about 5 mm. in the present state of preservation, originally probably 6 or 6.5 mm.

Type. From the same lot of specimens as those bearing the label Riviere des Hurons, and collected October, 1872, by Thomas Curry, and assumed therefore to come from the same locality, near St. Jean Baptiste, although the specimen here described does not bear a label. Preserved in the Paleontological collections, Geological Survey of Canada, Victoria Memorial Museum, Ottawa, Canada. No. 8426.

35. **Clidophorus planulatus,** Conrad

In the *Fifth Annual Report of the Geological Survey of New York*, published in 1841, Conrad described *Nuculites planulata* in the following terms:

> Compressed; ovate-acute; posterior dorsal margin oblique, rectilinear, extremity acutely rounded; basal margin regularly arched; rib oblique.
> *Locality*. Pulaski, Oswego county.

In the *Paleontology of New York*, vol. i, on plate 82, Figs. 9*a*, *b*, *c*, and *d*, all represent specimens of *Clidophorus planulatus* collected at Turin. Of these, the specimens represented by Fig. 9*a* are embedded in an arenaceous slate, associated with *Trinucleus concentricus*, *Zygospira modesta*, round and pentagonal columnals of crinoids, as at the type locality immediately east of Pulaski, along the river.

The following is a description of specimens collected by the writer at the type locality, along the river east of Pulaski, New York.

Shell transversely elliptical oblong, height about half the length of the shell, with the beak approximately a third of the length of the shell from the anterior end. Umbonal ridge low, distinctly defined along its cardinal border where it makes an angle of 162 to 165 degrees with the longitudinal axis of the shell. Above this umbonal ridge, the posterior cardinal slope of the shell is flattened and subalate. The posterior part of the hinge-line extends from the beak for a distance equalling about two-fifths of the length of the shell, and then makes an angle of about 150 degrees with the posterior margin of the shell. The margin is rather strongly rounded at both the posterior and anterior ends of the shell, the maximum curvature of the anterior margin, however, being nearer the hinge-line. The basal margin is moderately and evenly convex. The clavicular adductor support anterior to the beak forms an angle of about 80 degrees with the longitudinal axis of the shell; it is comparatively straight and extends downward to about the middle height of the shell; it is sharp and narrow, appearing on the cast of the interior of the shell as a sharp incision not depressing the immediately adjoining part of the shell. The convexity of the shell is moderate, that of a shell 9 mm. in height being about 1.6 mm. Specimens 20 mm. in length occur. Com-

pared with the specimens figured by Hall from Turin, the Pulaski forms are relatively longer and hence are more convex along the anterior and posterior outlines.

It will be noted that all of the specimens of *Clidophorus planulatus*, from Turin, were figured by Hall as having more oblique clavicular adductor supports anterior to the beak. Figs. 9*b*, *c*, *d*, represent specimens imbedded in the shale. Of these, only specimen 9*d* presents a very oblique clavicle, approximately 55 degrees, while the original of Figs. 9*b* and 9*c* show angles as steep as 75 to nearly 80 degrees. Fig. 9*a*, although described as coming from arenaceous slate, may have come from about the same horizon as the shale specimens, since thin arenaceous layers often are interbedded in the Lorraine shale. This horizon may be lower than that of the type locality, in the river bed east of Pulaski. It is evident from the figure that the rock fragment contained also *Trinucleus*, *Zygospira*, and columnals of *Heterocrinus* and *Glyptocrinus*. Similar specimens, with more oblique clavicular adductor supports occur also at Rome, New York. One of these specimens, taken from the series numbered R–1232 in the State Museum, at Albany, New York, is here represented by Fig. 13, on plate I. It is not certain, however, whether these specimens with the more oblique clavicular adductor support impressions should be regarded as distinct from the forms with more vertical impressions. Occasional specimens from the type locality, east of Pulaski, also have very oblique clavicular adductor supports, forming angles of 65 degrees with the longitudinal axis of the shell. This angle may vary in different individuals of the same species.

36. **Clidophorus praevolutus,** sp. nov.

(*Plate I, Fig. 12, type; two figures under 6, cotypes*)

Transversely elliptical; length 11.5 mm.; height 5.2 mm.; ends narrowly rounded. Anteriorly the shell extends 3.5 mm. in front of the beak; here the cardinal outline is comparatively straight and forms an angle of about 165 degrees with the hinge-line back of the beak. Posteriorly there is a narrow concave subalate cardinal slope, scarcely a millimeter wide at its posterior end; along this part of the shell the hinge-line is straight for a distance of about 5 to 6 mm. and then joins the upper part of the posterior margin

at an angle of about 120 to 125 degrees. Surface marked by fine concentric lines, not readily seen except under a lens. Cast of interior with a narrow, slightly sigmoid, clavicular adductor support impression just in front of the beak, forming an angle of 65 degrees with the longitudinal axis of the shell, and extending about 2.5 mm. from the tip of the beak. Anterior to this clavicular support groove a shallow depression extends across the shell from the beak to the anterior part of the basal margin at an angle of about 55 degrees with the longitudinal axis. Anteriorly this shallow depression is bounded by a low transverse ridge or fold, also extending from the beak toward the anterior part of the basal margin, at an angle varying from about 45 degrees near the beak to 50 degrees near the basal margin. It is the shallow depression and low ridge or fold anterior to the clavicular support impression in the cast which are regarded as most typical of the form here described.

Type. Richelieu River, near Chambly, collected by A. H. Foord in 1881. No. 2079, in Paleontological collections, Geological Survey of Canada, Victoria Memorial Museum, Ottawa, Canada. Associated with *Glossograptus quadrimucronatus-approximatus*, and *Rafinesquina alternata.* The type is represented by Fig. 12 on plate I.

The two specimens represented by Fig. 6 on the same plate are regarded as belonging to the same species. They occur on the rear of the rock fragment containing the type of *Psiloconcha sinuata-borealis*. This fragment came from a group labelled as coming from the Riviere des Hurons, and as collected by Thomas Curry, in October, 1872, but no label is attached to the fragment itself. No. 8427.

All of the figures are unsatisfactory, owing to the small size of the specimens. The engraver did not preserve well the outlines of the valves although these were clearly shown in the photographic reproduction on the copper plate. Compared with *Clidophorus planulatus,* the valves are relatively lower and longer, and the clavicular adductor support is more oblique, although the amount of this obliquity apparently is a variable feature.

Specimens resembling *Clidophorus praevolutus* occur also half a mile south of the station at St. Hilaire, in a ditch along the road.

37. **Ctenodonta lorrainensis,** sp. nov.

(*Plate III, Figs. 8 A, B*)

Shell rotund in outline, the length and width being about equal. The outline, however, is not strictly circular, there being a slight tendency toward angulation at the posterior extremity, owing to a straightening of the posterior part of the arcuate hinge-line, as in *Ctenodonta pectunculoides*, Hall, from the Mt. Hope and Fairmount beds of the Maysville division of the Cincinnatian, at Cincinnati, Ohio. In the latter species, however, the tendency is toward a greater length than height of the valves, while in *Ctenodonta borealis*, the tendency is toward a slightly greater height than width. This results in a less angulate posterior outline. Moreover, the height of the hinge area, compared with the rest of the shell, is less. Surface with very fine concentric striae, readily seen only under a lens.

Ctenodonta cingulata, Ulrich, was described from the Gasteropod layer at Marble Hill, Indiana. This is a layer several feet thick, and about 65 feet above the horizon at which *Leptaena richmondensis-precursor*, and *Dinorthis carleyi*, the characteristic fossils of the middle part of the Arnheim, occur. Ten feet below this Gasteropod layer, at Scott Hill, in Trimble county, Kentucky, there is a horizon full of *Tetradium* and *Stromatocerium*, immediately overlying a zone, about 15 feet thick, in which *Homotrypella hospitalis* is common. This gasteropod layer is regarded as belonging to the lower part of the Waynesville section, although the characteristic brachiopod fauna of the Richmond is found in this part of Indiana and Kentucky only at a considerable distance above the Gasteropod layer. Compared with *Ctenodonta lorrainensis*, *Ctenodonta cingulata* is larger, has a much thicker shell, the hinge area is higher, especially at the beak, and the teeth here are much longer, narrower, and more crowded.

Ctenodonta pulchella, Hall, was described from the black slate near Watertown, New York. This black slate is interbedded with the limestone at the base of the Trenton section. The specimen represented by Figs. 12*a*, *b*, on plate 82, of vol. I, *Paleontology of New York*, is listed as number 1064 in the collections of the American Museum of Natural History. This species, judging by the published figure, is readily distinguished from

Ctenodonta lorrainensis by the relatively greater length of the shell, compared with its height.

Locality. *Ctenodonta lorrainensis* occurs along the creek, northeast of the bridge at the eastern edge of the village of Lorraine, New York. The same species is even more abundant where the road to Worthville crosses the creek, two miles west of Worthville, and since the latter are best preserved, they are chosen as types.

Similar nearly rotund specimens of *Ctenodonta* occur in Canadian strata referred to the Lorraine. The valves appear to be slightly more convex; the hinge area, a little higher; and the teeth a little stronger and more erect, but the differences are slight. An excellent cast of the interior, numbered 2083, was collected on the Richelieu River, at Chambly, in 1881, by A. H. Foord. It is associated in the same rock fragment with *Pholidops subtruncatus, Protowarthia cancellata, and Glossograptus quadrimucronatus-approximatus.* Similar specimens occur at St. Hilaire in the ditch along the road leading off southeastward from the station. The exposures are about half a mile distant from the railroad.

38. **Lyrodesma poststriatum,** (Emmons) Hall

(*Paleontology of New York, vol. I, Plate 82, Figs. 10 A, B, 1847*)

Lyrodesma poststriatum was figured by Emmons among Utica fossils from Jefferson county, apparently because he had found this species associated with *Triarthrus.* If so, he found his type at a much lower horizon than the large specimen figured by Hall, from Pulaski, a short distance south of that county. At Pulaski it occurs beneath the railroad bridge and also at the *Trinucleus* horizon, several hundred yards west of the bridge. It occurs northeast of the bridge within the limits of the village of Lorraine; also at Worthville, and two miles west of Worthville, where the road to Lorraine crosses a creek. It is found at a higher horizon at the power house at Bennett bridge, a little over a mile west of Salmon River Falls, and also half a mile eastward, a short distance below the level of the base of the falls.

In the large specimen figured by Hall, the upper part of the anterior outline is more rotund; apparently four simple plications occur above the umbonal ridge, followed by several fascicles of

finer striae. The specimen is not properly cleaned and the figure needs republication.

In the province of Quebec, the same species occurs at several localities in the Lorraine between Ottawa and Vars; also on the Richelieu River at Chambly, and two miles northwest of St. Hugues on the Yamaska River.

Lyrodesma plana was described by Conrad from the fossiliferous sandstones at the base of the Oswego sandstone section, near Rome. The types have been lost and no specimens have been discovered since the original description was published.

39. **Rhytimya oehana,** Ulrich

(*Plate I, Fig. 11*)

The shell is strongly compressed, the thickness from valve to valve being scarcely more than 4 mm.; original thickness unknown. Basal margin slightly concave, the mesial sulcus practically obsolete, the surface anterior to the umbonal ridge being flattened rather than depressed. Posterior outline, at the end of the umbonal ridge, angular rather than rounded. Surface strongly striated and wrinkled concentrically, the wrinkles being increased to strong folds anteriorly. Above the umbonal ridge the wrinkles become faint but the striae remain distinct. The characteristic oblique rows of punctae or granules may be detected from the anterior fourth of the shell to the umbonal ridge posteriorly.

Locality. Richelieu River at Chambly, associated in the same rock fragment with *Catazyga headi, Pholidops subtruncatus,* and *Cleidophorus praevolutus.* Collected in 1912 by Aug. F. Foerste. Preserved at the Victoria Memorial Museum, at Ottawa, Canada, by the Geological Survey of Canada. No. 8423.

40. **Cuneamya scapha—brevior,** var. nov.

(*Plate II, Fig. 12*)

Shell closely related to *Cuneamya scapha,* but relatively shorter, and hence with a less inclined umbonal ridge and mesial sulcus. The angle between the umbonal ridge and the hinge-line is approximately 45 to 50 degrees, the median part of the mesial sulcus forming an angle of about 70 degrees. The mesial sulcus has a

width of about 15 mm. near the basal margin, and is distinct even close to the beak, although this may be only an individual characteristic. The beak is broader and far less acute than is indicated in the figure of the type presented in the second volume of the Paleontology of Ohio. The anterior outline, however, is closely similar. The umbonal ridge is rounded, not angular, and the posterior margin is more evenly rounded posteriorly. Concentric striae or low narrow undulations fairly distinct anteriorly, becoming fainter along the umbonal ridge and on the cardinal slope.

Length 32 mm.; height at posterior end 18 mm.; height at beak 20 mm.; extension of shell anterior to beak about 3 or 4 mm.; length of lunule about 7 or 8 mm.

Type of the variety here described: Riviere des Hurons, near St. Jean Baptiste, collected October, 1872, by Thomas Curry. Preserved in the collections of the Geological Survey of Canada, in the Victoria Memorial Museum, at Ottawa. No. 8407.

Specimens apparently identical with *Cuneamya brevior* occur half a mile south of St. Hilaire station, in a ditch along the road, a mile and a half northwest of Vars at a crossing of two country roads. Along the Nicolet River, southwest of Ste. Monique, in the lower part of the Proetus chambliensis zone.

41. **Archinacella clochensis,** sp. nov.

(*Plate II, Figs. 5 A, B*)

Among described species, this form most nearly approaches *Archinacella orbiculata*, Hall, from the lower Trenton or Snake Hill shale of eastern New York, and *Archinacella subrotunda*, Ulrich and Scofield, from the Ctenodonta bed of the Black River group in Minnesota.

Shell suboval, about 13 mm. long, 11 mm. wide, and slightly over 4 mm. high. Obliquely subconical, with the apex about 1 or 1.5 mm. vertically back from the anterior margin. In profile view, moderately concave between the apex and the anterior margin, and rather evenly convex between the apex and the posterior margin. The area of highest elevation is not at the apex but about 3 mm. posterior to the same. This profile view agrees most closely with that presented by Ruedemann of one of the types

of *Archinacella orbiculata,* Hall,[4] but the beak is less incurved, the concentric striations are finer, and there is an absence of the stronger, nearly equidistant lines of growth shown by both of Hall's types. Compared with *Archinacella subrotunda,* the shell is distinctly longer. The form here described from the Lowville is probably an undescribed species.

Locality. From the basal red clay shales of the Lowville, on the western shore of La Cloche peninsula, a short distance above railroad level. Collected in 1912 by Aug. F. Foerste, and preserved in the Victoria Memorial Museum, at Ottawa, by the Geological Survey of Canada. No. 8418.

42. **Archinacella pulaskiensis,** sp. nov.

(*Plate III, Figs. 3 A, B, C, D*)
Paleontology of New York, vol. i, Plate 83, Figs. 7a, 7b

The form figured by Hall from the Lorraine at Pulaski, New York, as *Archinacella patelliformis,* differs in outline from his Trenton types, which were derived from the dark, compact, Trenton limestone at Middleville, New York. This shell is broader and more convex along the middle and the outline, therefore, is rather broadly ovate than ovate oblong. Otherwise the two shells are closely similar. The beak extends almost or fully as far forward as the anterior margin of the shell. It overhangs this margin by an anterior slope which on lateral view is not so strongly concave. The beak is rather pointed, especially when viewed from above, and there is a tendency toward carination for a moderate distance posterior to the beak. The highest part of the shell is about five-twelfths of the length of the shell from the anterior margin. The shell is smooth, surface striations being faint or absent.

The type of the species occurs in the same rock with *Modiolopsis modiolaris, Byssonychia radiata, Hormotoma gracilis, Dalmanella,* and *Glyptocrinus* columnals.

This species occurs at the *Trinucleus* horizon, several hundred yards west of the railroad bridge across the river, east of Pulaski. It is found also northeast of the bridge within the limits of Lorraine village, and along the creek within the boundaries of Barnes

[4] The Lower Siluric Shales of the Mohawk Valley, *Bulletin 162 of New York State Museum,* plate 7, Fig. 6.

Corners. It is found also at the power house at Bennett Bridge, a little over a mile west of the Salmon river Falls.

The same species occurs in the province of Quebec, on the Richelieu River at Chambly. (No. 8434, in Victoria Memorial Museum, Ottawa, Canada.) A similar form is found on the Nicolet River, southwest of Ste. Monique, about 575 feet below the lowest horizon containing *Strophomena planumbona.*

The type of *Protowarthia cancellata,* Hall, was obtained at Lorraine; *Cyrtolites ornatus* was described by Conrad from Washingtonville, from a horizon approximately equivalent to that at the railroad bridge east of Pulaski. The types of *Hormotoma gracilis* and *Clathrospira subconica* were obtained from the Trenton at Watertown.

43. **Lophospira beatrice,** sp. nov.

(*Plate II, Figs. 8 A, B*)

The *Murchisonia beatrice,* Billings, listed in the *Geology of Canada* in 1863 from the Riviere des Hurons is as good a species of *Lophospira* as many another form of this genus, although undoubtedly closely related to *Lophospira bowdeni,* Safford. The specimens figured by Safford represent one extreme of development, with apical angles of 27 to 30 degrees, and with 8 to 10 volutions of which 6 or 7 are usually preserved, the tip being broken off. The characteristic feature of this group of shells is the rather broad and convex peripheral band, situated slightly below the center of the whorl, varying considerably in prominence but usually far less angular than in most species of this genus. Upper slope flattened or moderately concave toward the peripheral band, angulated or obscurely carinated where it curves into the rather deep sutural area. The lines of growth are strongly recurved toward the peripheral band, which they cross as rather broadly concave lines, indicating a rather broad notch in the outer lip. There are no raised lines or striae bordering the upper and lower parts of the peripheral band, as in so many species of the genus. A lower carination or angulation usually obscure but sometimes fairly distinct, ending near the upper margin or the inner lip, is seen on the last volution of some specimens. The aperture is not well preserved in any specimens at hand but enough is preserved to indicate that it had essentially the same form as

that of *Lophospira bowdeni*. The chief difference between *Lophospira beatrice* and typical *Lophospira bowdeni* consists in its larger apical angle, apparently averaging about 35 degrees but varying from 30 to 38 degrees. This produces a shorter shell, so that the greater number of specimens, in their present state of preservation, present only four or five volutions although the complete shells probably possessed seven or eight.

The types formed part of a small group of shells in a small tray in the collections of the Geological Survey of Canada, at the Victoria Memorial Museum, at Ottawa, Canada. They were accompanied by the original printed label used for the Billings types, bearing the following information: *Murchisonia beatrice,* Billings. Riviere des Hurons. Hudson river group. Collected by James Richardson. 8A is numbered 8417; 8B, 8417*a*. This species was named, but not described or figured, by Billings.

Similar, if not identical forms, exist in the Richmond exposures three-fourths of a mile west of Vars, and also along the Nicolet River, southwest of Ste. Monique. They were not detected in the great Lorraine section, along this river.

44. **Ruedemannia abbreviata,** Hall

The species described by Hall as *Murchisonia uniangulata,* variety *abbreviata,* in the *Paleontology of New York,* vol. I, page 304, belongs to the Robusta section of the genus *Lophospira,* as divided by Ulrich in his Monograph on the Lower Silurian Gasteropoda of Minnesota. The type of *Lophospira abbreviata* was found at Pulaski, in rock containing *Calymene, Orthoceras* with transverse striae as in *Orthoceras lamellosum, Cyrtolites ornatus, Hormotoma gracilis, Byssonychia radiata,* and the common Lorraine form of *Dalmanella.* Apical angle between 60 and 65 degrees. The transverse striae form a strongly reëntrant angle toward the peripheral band. This band is tricarinate, or trilineate; in typical specimens, the middle line is scarcely more prominent than the other two; the intermediate spaces are concave. The slope of the whorl above the peripheral band is gently convex excepting in the immediate vicinity of the band where it is gently concave. That part of the whorl which is below the peripheral band is evenly and somewhat more strongly convex. Since two specimens are present on the same rock fragment,

numbered 1136–1, in the American Museum of Natural History, in New York, I have chosen the one showing the trilineate peripheral band to best advantage as the type, since this specimen unquestionably furnished the material for Fig. 2*c* on plate 83, accompanying Hall's description. A third specimen occurs in the same rock as what I regard as the type of *Ormoceras crebriseptum*, namely figure 2*b*, on plate 87. The vertical striae of this *Ormoceras* belong only to the exfoliated interior of the shell, and the appearance of the surface is unknown. The trilineate peripheral band of the *Lophospira abbreviata* is well shown, and there is a trace of a revolving angulation very much farther down than in *Lophospira lirata*, Ulrich. There is no trace of an angulation on the upper slope.

Shells of this type, with subrotund whorls and trilineate peripheral bands, the three lines nearly subequal, appear sufficiently distinct from the typical forms of *Lophospira* to receive a distinct designation. For this reason the term *Ruedemannia* is here proposed, in honor of Dr. Rudolph Ruedemann, as a slight recognition of his monumental labors on Paleozoic fossils. As a type of this genus, *Lophospira lirata*, Ulrich, from the Eden formation at Cincinnati, has been selected, because the New York species here described appears more closely related to the *Lophospira lirata* of Ulrich than to the *Pleurotomaria robusta* of Lindstroem. The presence of revolving striae is not regarded as essential. I assume, in the absence of further data, that the *Lophospira lirata* of Ulrich is identical with the *Pleurotomaria ohioensis* of James, a species from the Cincinnatian of Ohio, but from a horizon not designated by the author. The type of *Lophospira lirata*, Ulrich, forms No. 45904 in the collections of the U. S. National Museum.

45. **Pterotheca** cf. **attenuata,** Hall

(*Plate II, Fig. 3*)

A small species of *Pterotheca,* apparently belonging to the Pterotheca attenuata group. Lateral margins gently convex, rounding more strongly into the posterior and anterior margins, resulting in a rounded quadrangular outline. Shell moderately convex, excepting at the carina which rises strongly above the general convexity of the shell. In a specimen 20 mm. wide and

17 mm. long, the general convexity is about 3 mm., but the anterior part of the carina rises nearly 4 mm. above the neighboring parts of the shell. The shell is concentrically wrinkled and striated, but these markings are not very conspicuous. The lateral lines of attachment of the septum are distinctly indicated and are illustrated by the accompanying figure.

Locality. In the basal red clay shales of the Lowville, along the western shore of La Cloche peninsula, several feet above railroad level. Collected in 1912 by Aug. F. Foerste, and preserved in the Victoria Memorial Museum, at Ottawa, Canada, by the Geological Survey of Canada. No. 8406.

46. **Pterotheca pentagona,** sp. nov.

(*Plate II. Figs. 1, 2*)

Shell symmetrical, moderately convex, at least in the present state of preservation, excepting close to the apex where the curvature of the shell toward the posterior margin is more pronounced. Posterior margin nearly straight or only moderately curved for a distance of 10 or 12 mm. on each side of the apex, and then curving forward toward the lateral margins of the shell. Lateral margins nearly parallel, converging from a width of 48 mm. at the rear to 40 mm. toward the front, where the lateral margin forms another angle, curving inward toward the median part of the shell. A fifth angle is formed anteriorly, where the margin curves forward on approaching the median wing or carina. The length of the shell from the apex to the anterior part of the carina is at least 35 mm. and possibly 37 mm. The antero-lateral angles are estimated as about 28 mm. anterior to a line drawn transversely through the apex.

Only the basal part of the carina along the anterior half of the shell is preserved. This suggests the presence of a carina at least 10 mm. in height, and possibly higher. The shell is finely striated concentrically, the striae following the lateral and anterior outlines of the shell; at the base of the carina they curve backward and upward suggesting a vertical slit anteriorly. In addition to the striae, the shell also is concentrically wrinkled, the wrinkles being best developed between the apex and the lateral margins. The lower side or aperture is partly traversed by a broad triangular septum, with its apex at the apex of the shell, and with its

sides attached to the main body of the shell along straight or moderately curved divergent lines, forming an angle of about 75 degrees with each other, this angle becoming more acute near the apex. The lines of attachment are about 20 mm. long, equalling from two-thirds to three-fourths the length of the shell from the apex to the antero-lateral angles. The striae upon the inner surface of this septum indicate that its anterior edge was moderately convex. Seen from the lower side of the shell, the septum was moderately concave; at the apex the shell is only moderately incurved. Convexity, aside from the dorsum, estimated at 5 to 7 mm., but the shell may be more or less vertically compressed as it lies in the rock.

Type. Richelieu River, near Chambly, collected 1881 by A. H. Foord. No. 2155, Paleontological collections, Geological Survey of Canada, Victoria Memorial Museum, Ottawa, Canada. Fig. 1, on plate II.

Another specimen, plate II, Fig. 2, referred to *Pterotheca pentagona,* was found by the writer on the Nicolet River, southwest of Ste. Monique. This specimen occurred associated with a variety of *Leptaena rhomboidalis, Rafinesquina mucronata, Catazyga erratica, Proetus,* and numerous other species, at a horizon 820 feet below the lowest strata in this section in which *Strophomena planumbona* and *Rhynchotrema perlamellosa* are found. *Trinucleus* and *Triarthus* occur 730 feet below this *Pterotheca pentagona* horizon. This second specimen also is preserved in the Victoria Memorial Museum, and is numbered 8409.

Pterotheca transversa was described in 1852 by Salter, under the term *Cleodora transversa,* in the *Report of the British Association* for 1851, on page 64, from Desertcreat, Tyrone, in Ireland. With this species the Canadian form has been erroneously identified.

47. **Cornulites,** sp.

At the *Strophomen nasuta* and *Trinucleus* horizons, between the railroad bridge, about a mile east of Pulaski, and a point several hundred yards westward, down the stream, there is a form of *Cornulites* with a free habit of growth, and practically straight or only slightly curved. These straight forms are known usually as *Tentaculites.* At the initial tip it probably was attached to some other organism, but no evidence of such attachment was

found. The tubes are crossed by annulations, which are rather angular on the crest, sloping with about equal rapidity into the concave constrictions both above and below each annulation. Tube very thin, the interior cast also annulated; annulations sloping gradually in the distal direction, and abruptly on the proximal side; in fact, on the proximal side these annulations often are slightly incurved. Exterior with very fine and numerous longitudinal striations, often alternating slightly in size. At each annulation these longitudinal striae begin as very fine striae on the distal side of the crest, dip into the constricted parts, and become stronger on rising up the proximal slope of the next annulation. Of these longitudinal striae there are about 8 or 9 in a width of 1 mm. around the circumference, with an equal number of still finer, intermediate ones, visible under a lens in specimens preserved in fine grained strata. Transverse striations are present in some specimens, but can be seen only with a magnifier and under strong cross illumination. The length of the specimens at hand scarcely exceeds 15 mm. This is the species figured by Hall on plate 78 of the *Paleontology of New York*, in vol. I.

Two miles west of Worthville, on the road to Lorraine, another form occurs associated with *Trinucleus* and other fossils suggesting a fauna very similar to that east of Pulaski. In this form of Cornulites the annulations also are rather sharp along the crest, but they tend to slope more rapidly on the distal than on the proximal side. Their chief characteristic, however, is the coarseness of the longitudinal striae, which become so strong on ascending the proximal slopes that they give an almost nodular or scalloped appearance to the crest of the annulations. Of these nodules there are about 5 in a width of 1 mm. around the circumference. Under strong cross illumination very fine intermediate longitudinal striae can be seen, a single node sometimes representing the distal termination of two or even three striae. Transverse striae are readily distinguished under a lens in some specimens.

Although the two forms here described present quite a different general appearance, the second may be only a more vigorous form of the first, and a much more extended study is necessary to determine their degree of relationship.

In referring these tubes to *Cornulites*, the writer has merely followed Hall.[5] Cornulites flexuosa, Hall, was founded on a form

[5] *Paleontology of New York*, vol. vii, p. 8 of Supplement.

from the Trenton limestone, at Lowville, New York. I have been unable to identify either form, with certainty, with described species from Cincinnatian rocks, and the descriptions here given are intended merely to call attention to the chief characteristics observed, with the view of further collecting.

48. **Technophorus punctostriatus—quincuncialis,** var. nov.

(*Plate II, Figs. 13 A, B*)

The shell or carapace of the minute crustacean here called *Technophorus quincuncialis* so closely resembles that of *Technophorus punctostriatus*, Ulrich, that it can be best described by noting the differences. If a line be drawn vertically downward from the beak toward the basal margin, then the basal margin of *Technophorus quincuncialis*, posterior to this line, will be found to be more convergent with the dorsal margin, forming an angle of about 10 degrees with a horizontal line. Moreover, the two sigmoid ridges crossing the posterior half of the carapace, from the beak toward the lower part of the posterior margin, are more oblique, the anterior one forming an angle of about 40 to 43 degrees with a horizontal line; the convex part of the curve near the beak is relatively much longer, and the concave part, toward the postero-ventral angle, is correspondingly shorter. Only one specimen, among those at hand, shows the character of the ornamentation between the two sigmoid ridges, and in this case it consists of striae, about 3.5 in a width of half a millimeter; these striae are much wider than the concentric striae on the main body of the carapace but occur at about the same intervals as the concentric striae where the latter are most distant from each other on the anterior part of the body; in direction, they form angles of about 55 degrees with a horizontal line, or about 15 degrees with the general trend of the anterior sigmoid ridge, in this respect resembling *Technophorus divaricatus* rather than *Technophorus punctostriatus*. The posterior or cardinal wing, behind the second sigmoid ridge, bears no ornamentation of any kind on any of the specimens at hand. The interior ridge or so-called clavicle extending from the anterior part of the beak toward the basal margin is 2 mm. in length. Its position frequently can be detected on the exterior of the carapace. Along the upper part of the body, between the clavicle and the anterior sigmoid ridge, the

concentric striae ornamenting the exterior are approximately horizontal, but ventrally from this part of the body, the concentric striae become parallel to the lower margin. Anterior to the anterior sigmoid ridge, for distances varying from 1.5 mm. toward the dorsal margin, to 2.5 mm. near the middle, and from 5 to 6 mm. near the basal margin, the spaces between the concentric striae are crossed by short transverse striae which are more closely crowded toward the sigmoid ridge, but become more distant anteriorly; over the central parts of the main body the ornamentation takes more of the nature of circular or rounded hexagonal pits having a quincuncial arrangement. Directly below and in front of this quincuncially ornamented area, however, within seven-tenths of a millimeter of the ventral and anterior margins, only the concentric striae are distinctly indicated.

Type. Chambly, Richelieu River, collected in 1881 by A. H. Foord; No. 8415. The same slab contains also specimens of *Pholidops subtruncatus*, Hall, and a free cheek of *Proetus chambliensis.* A second specimen, No. 8413, from the same locality, came from a layer containing an abundance of *Plectambonites rugosa*, Meek, associated with *Catazyga headi.* A third fragment of rock, numbered 2076, contains not only the *Technophorus*, but also *Pholidops subtruncatus* and *Byssonychia radiata.* A fourth specimen, displaying chiefly the interior characters of the carapace, shows the perpendicular ridge called the clavicle in the preceding description. The accompanying illustrations are not adequate for presentation of the characteristics of this species.

It is probable that all of the species of *Conocardium* described from Ordovician strata are to be regarded as crustaceans. This is true certainly of *Conocardium* (*Pleurorhynchus*) *antiquum*, Owen, *Conocardium elegantulum*, Billings, and *Conocardium richmondensis*, Foerste. None of these shells have a true beak or hinge area as in lamellibranchiata, and they form a new genus of crustaceans. *Conocardium immaturum*, Billings, probably represents a second new genus of crustaceans.

49. **Cryptolithus tessellatus,** Green

In his description of *Trinucleus concentricus*, Hall states that: "The specimen figured by Green, is one before referred to, as coming from the slates of the Hudson-river group, near Waterford, which at that time were regarded as almost non-fossil-

iferous." Moreover, Green himself, in his *Monograph of North American Trilobites,* states: "Mr. Eaton says that *Nuttainia concentrica* 'occurs in the wacke variety of transition of argilites on the Champlain canal,' between the town of Waterford and the Mohawk river. The specimen in my cabinet, from which our cast was made, is from that place."

The rather meager fauna so far discovered at Waterford has been found, by Dr. Rudolf Ruedemann, to belong stratigraphically to the Snake Hill beds, which at the type locality, on the east side of Saratoga Lake, contain a much larger fauna, placed by Dr. Ruedemann near the base of the Trenton, below the Canajoharie shale.

It is scarcely likely that the *Trinucleus* found in the Pulaski division of the Lorraine belongs to the same species as this Snake Hill form, but no material is at hand by means of which the two forms may be discriminated.

The following is a description of a series of specimens occurring in a single block of finegrained Lorraine rock from which most of the lime had been dissolved, leaving the specimens in the form of of casts of the upper and lower surfaces of the cephalon.

Glabella obovate, tumid in front, becoming lower and narrower posteriorly; at the posterior margin of the cephalon its width is equal to half, or slightly less than half the width of the glabella anteriorly. Here the posterior end of the glabella is crossed by the nuchal furrow in a direction convex to the rear, posterior to which the glabella extends with a rounded V-shaped outline, projecting behind the posterior margin of the cephalon a distance about equal to the width of the glabella at this margin. Posteriorly, this nuchal V-shaped segment of the glabella terminates in a sharp narrow spine about 2 mm. in length, always present, but generally overlooked. On each side of the posterior part of the glabella, in the nuchal groove, and also a very short distance anteriorly, there is a small depression or pit which is the only evidence of segmentation shown by the glabella. The glabella rises an amount equal to almost half its width above the general convexity of the cheeks. The latter are moderately convex over most of their surface, becoming slightly tumid only laterally, where they adjoin the pitted border. A narrow groove separates the cheeks from the equally narrow raised posterior border of the cephalon. For two-thirds the width of the cheek, the posterior

border of the cephalon is directly at right angles to the longitudinal axis of the cephalon, and then curves diagonally backward toward the genal spines. The pitted area extends, from the pitted lateral border, around the postero-lateral part of the cheeks almost as far as the point at which the posterior border of the cephalon begins to curve diagonally backward. Anterior to the glabella there are four concentric rows of pits, which remain distinct as far as a point opposite the posterior margin of the free cheeks. A fifth row is intercalated between the third and fourth rows from the front, at a point almost directly in front of the middle of the cheeks, and a sixth row is intercalated between the fourth row and the cheeks, a little anterior to the mid-length of the latter.

The first two rows of pits, counting from the anterior margin, may be distinguished from the remainder by the fact that for about two-thirds of the width of the cephalon the pits of these two rows are vertically in front of each other and the line of separation between the members of each pair depressed, so that here the pitted border consists of a lateral succession of pairs of pits sunk into a common depression. Specimens differ widely as to the degree in which this appearance of a lateral succession of pairs finds expression. Toward the genal angles, the pits of these first two rows become alternate. The pits on the lower surface of the cephalon correspond in position to those on the upper surface, and between the first and second rows on this lower surface, there is a raised ridge which may be traced backward into the genal spines. In well preserved specimens the latter extend straight backward, continuing in the direction of the lateral border of the cephalon. Specimens differ greatly in their relative width and length, probably due to different degrees of depression of the convex cephalon, but the best preserved specimens show a ratio of 44 per cent between the length of the cephalon, as far back as its straight posterior border, and its width.

The specimens here described were obtained from a block in the upper part of the Gulf west of Turin, near the upper part of the road ascending southwestward toward a school house on the pike. Here it lay with other similar rocks along the side of the road, as if thrown out of a ditch while repairing the road. The same block contained a flat form of *Zygospira,* somewhat resembling some of the smaller specimens referred to *Zygospira cincin-*

natiensis, *Rafinesquina alternata*, *Cyrtolites ornatus*, *Liospira vitruvia*, *Protowarthia cancellata*, *Cymatonota pholadis*, *Byssonychia radiata*, *Calymene*, and several new species of gasteropoda. The horizon is regarded as below that at Pulaski, but how far is not known. The *Zygospira* above mentioned is the one figured by Hall, in the *Paleontology of New York*, vol. I (plate 79, Fig. 6), probably from Turin, as *Atrypa increbescens*.

With these specimens described from the block found in the upper part of the Gulf, west of Turin, the forms of *Trinucleus concentricus* found in the *Rafinesquina nasuta* block, west of the railroad bridge, a mile east of Pulaski, and those found in situ at Pulaski, Lorraine, and numerous other localities in the middle Lorraine, appear to agree perfectly, but better specimens are needed for final determination.

50. **Calymene conradi,** Emmons

The following description of *Calymene conradi* was published by Emmons in his *American Geology*, p. 236, in 1856:

> Small, wide across the cheeks; cheek angles obtuse or rounded; posterior lobes of the glabella comparatively large and globular; thoracic lobes very convex, with a row of tubercles in the furrow or between the axis and the lateral lobes. Lorraine shales.

The fact that this species was described nine years after the publication of vol. I, of the *Paleontology of New York* suggests that Emmons, in his description was trying to distinguish the Lorraine form from the published figures and description of *Calymene senaria* as given by Hall. If so, it will be necessary to establish the species upon other grounds than those cited, although it is practically certain that the Lorraine form of New York is specifically distinct from the *Calymene senaria*, typically found in the Trenton limestone of that state.

51. **Proetus chambliensis,** sp. nov.

(*Plate IV, Figs. 1A–H*)

The specimens here described (No. 8435, in Victoria Museum) lie flattened in a small rock fragment collected on the Richelieu River, at Chambly, Quebec, a short distance west of the dam.

Surface practically smooth under an ordinary lens. In one

specimen the length is 14.5 mm. The length of the cephalon along the median line is nearly 5 mm. The length of the thorax is 5.5 mm. The length of the pygidium, 4 mm. The length of the head to a line connecting the tips of the genal spines is 7.5 mm.

The width of the head between the tips of the genal spines slightly exceeds 10 mm. The width of the anterior part of the thorax is about 9 mm. For about 6 segments, the width of the thorax remains about the same, but it becomes narrower posteriorly. The width of the pygidium is about 6 mm.

The width of the posterior part of the glabella is about 3.5 mm. The length of the glabella, as far as the nuchal groove, is 3 mm. As in other species of *Proetus*, the glabella is slightly enlarged posteriorly, where it adjoins the concave curvature of the large palpebral lobes. A short, faint groove, scarcely 1 mm. in length, starts opposite the middle of the palpebral lobe and extends diagonally backward, limiting the anterior part of the posterior pair of lateral lobes of the glabella. A second, fainter groove extends diagonally inward and moderately backward from about the anterior edge of the raised rim of the palpebral lobe. The distance from a line connecting the lateral terminations of this second pair of grooves as far as the anterior edge of the glabella is 1 mm. A third, still shorter and fainter pair of grooves is found anterior to the second pair and is scarcely visible.

The facial suture starts slightly exterior to a point directly in front of the palpebral lobe, curves diagonally inward, apparently follows the outer edge of the lobe just below the visual surface, and posteriorly bends outward again at an angle of about 45 degrees with a directly transverse line, cutting the posterior margin of the cephalon within 1.5 mm. of the longitudinal furrow limiting the axial lobe of the thorax, and an equal distance from the groove limiting the inner edge of the border of the cephalon at the genal angle. The visual surface is smooth and has a lunate form.

At the genal angle, the marginal border of the free cheek has a width of about four-fifths of a millimeter. The length of the genal spine is 2.5 mm., in the case of the specimen here described, but in a larger specimen on the same rock fragment, it equals 3.5 mm.

Anteriorly, the glabella is distinctly defined, and is separated from the marginal border of the cephalon by a narrow space about

equalling the width of the border, the two together equalling about four-fifths of a millimeter.

The axial lobe of the thorax has a width of fully 3.5 mm., narrowing to 2.5 mm. at the anterior end of the pygidium.

The number of pleural segments is ten. A median groove follows the lateral lobes of these segments laterally to the point where they curve posteriorly. The length of this posteriorly directed part is approximately between 1 and 1.5 mm.

Axial lobe of pygidium distinctly defined posteriorly as well as laterally. Its length is 2.8 mm. in a pygidium whose length is 3.8 mm., the flattened marginal border of the pygidium having a width of 1 mm. Essentially the same width of border is shown posteriorly by pygidia which have a length of nearly 5 mm.

The anterior annulation of the axial lobe of the pygidium, which is in contact with the thorax, is relatively narrow but strongly defined. The second annulation is the first one fully exposed, and is always very distinct. It is followed by one fairly distinct annulation, three much less distinct annulations, and rarely by another scarcely perceptible annulation, the last being followed by a space having room for two more annulations, where, however, none are present.

On the lateral lobes of the pygidium, the anterior pleural segment, adjoining the pleural segments of the thorax is strongly marked posteriorly. The next pleural segment is the first one fully exposed; this is fairly distinct, and has an indication of a median groove. This is followed by two much less distinct indications of pleural segments with no trace of a median groove, followed by another, scarcely perceptible pleural segment. The first fully exposed pleural segment extends across the flattened border of the pygidium. The remainder scarcely affect the border. The flattened border of the pygidium is relatively broad and slightly concave.

The specimens here described were obtained at Chambly Canton, on the southern side of the Richelieu River, a short distance below the dam. It occurs also at several localities east of Ottawa, among these: about a mile northwest of Hawthorne station; also along the road reached by going three quarters of a mile west of Vars, along the railroad, and then from half a mile to a little more than a mile northwestward along the public road. Along the Nicolet River, southwest of Ste. Monique, *Proetus* ranges from

533 to 1002 feet below the lowest horizon containing *Strophomena planumbona* and *Rhynchotrema perlamellosa.*

At the locality at the cross roads found by going three-quarters of a mile west of Vars, along the railroad, and then more than a mile northwestward, *Proetus chambliensis* is found associated with the following fossils: columnals usually referred to *Glyptocrinus, Dalmanella, Rafinesquina mucronata, Plectambonites, Zygospira modesta, Pholidops subtruncata, Byssonychia radiata, Clidophorus* resembling *praevolutus, Cymatonota pholadis, Cuneamya scapha-brevior, Lyrodesma poststriatum, Psilonychia inornata, Rhytimya* belonging to *oehana* group, *Eotomaria, Bythocypris cylindrica, Ctenobolbina* resembling *ciliata, Acidaspis,* and *Calymene.*

Along the same country road, west of Vars, but scarcely half a mile north of the railroad, *Proetus chambliensis* occurs associated with: columnals usually referred to *Glyptocrinus, Rafinesquina mucronata, Plectambonites, Pholidops subtruncata, Clidophorus* resembling *praevolutus,* and *Pterinea demissa.* The loose blocks in the neighboring fields, probably from various horizons, including even Richmond boulders, contained the following additional species: *Hebertella occidentalis, Strophomena sulcata, Zygospira modesta, Catazyga headi,* and *Clathrospira* closely resembling *subconica.*

Along the railroad, a mile northwest of Hawthorne station, *Proetus chambliensis* occurs associated with the following species: columnals usually referred to *Glyptocrinus, Pholidops subtruncatus, Dalmanella, Plectambonites, Rafinesquina mucronata, Hebertella occidentalis, Zygospira modesta, Lyrodesma poststriatum, Pterinea demissa, Ctenodonta lorrainensis, Cornulites, Bythocypris cylindrica,* and *Calymene.* In addition to these, loose blocks contain *Catazyga headi, Byssonychia radiata,* and *Isotelus.*

The exposures between Ottawa and Vars include representatives chiefly of this *Proetus* zone, with one exposure containing Richmond fossils, and one containing *Triarthrus,* and belonging near the base of the Lorraine. There is no trace of the *Leptaena* zones belonging between the *Proetus* and *Triarthrus* zones, as exposed along the Nicolet River. While it is very probable that the Lorraine section thins westward from the Nicolet River toward Ottawa, it also is probable that a considerable part of the failure of missing zones to appear in the Ottawa area is due to faulting.

Proetus parviusculus, Hall, was described from Cincinnati,

Ohio. There it is listed by John M. Nickles from the Corryville horizon. The glabella is rotund oval, without visible lobation. The border of the cephalon is broad and flat, even anteriorly, and defined from the remainder of the cephalon by its more nearly horizontal slope as well as by the shallow groove; there is no additional narrow elevation along the margin of the border. Thoracic segments comparatively prominent. Pygidium with prominent axis, and flat lateral lobes having a plain expanded border; lateral lobes with about four indicated segments, becoming indistinct posteriorly, the first two with longitudinal furrows. In *Proetus chambliensis* the glabella is relatively longer and more oblong oval in outline. It presents not only fairly distinct indications of the large basal lobes, but also indications of the middle pair, the limiting furrows being readily distinguishable under a lens. Along the outer margin of the flat border of the cephalon there is a very narrow elevated line, which becomes broader and more prominent just before reaching the anterior part of the facial suture, and which gives rise to the strongly defined marginal elevation of the cephalon at the edge of the border anterior to the glabella. The eyes are relatively longer and more closely appressed to the glabella. The thoracic segments are less prominent, especially along the axial lobe. The axial lobe of the pygidium rises strongly above the very moderately convex lateral lobes, and only the anterior segments are distinctly indicated. While unquestionably closely related to *Proetus parviusculus*, it seems possible to distinguish the Canadian forms for the reasons indicated.

52. **Byssonychia carinata,** Goldfuss

(*Petrefacta Germaniae, vol. II, p. 136, pl. 119, Fig. 8.*)

From the single figure accompanying this description it is evident that the form is a species of *Byssonychia*. Twenty-two plications are indicated between the posterior margin and the abrupt descent of the umbonal ridge at the anterior face; possibly 5 more plications belong to the anterior face, making a total of 27 plications, as figured. The original specimen may have had more, especially toward the posterior margin of the hinge-line. The general outline of the shell is not rotund but obliquely quadrate oblong with the greater axis in an approximately vertical

direction, somewhat as in *Byssonychia praecursa*, Ulrich, described from the Lorraine shales of Lorraine, New York. The original description states that, anteriorly, the shell is strongly arched or convex, and steeply or abruptly cut off. This type of structure occurs in *Byssonychia praecursa* and *B. richmondensis*. In the figure presented by Goldfuss, the abruptness and flattening of the anterior face is not strongly indicated, but is suggested by the considerable width of the anterior face, both valves being present in the individual figured.

The following description was presented by Goldfuss:

Pterinea testa ovata ventricosa obliqua antice abrupta postice declivi, margine cardinali brevi, ala postica truncata, costis radiantibus regularibus convexis, interstitiis latioribus plano-concavis.

Occurit in Psammite Americae septemtrionalis et Provinciae montanae. M. B.

Steinkerne dieser Art kommen bei Lewistown in Oneida-County und im Bergischen in der Grauwacke vor. Sie sind eyfoermig, vorn hochgewoelbt und steil abgeschnitten, nach hinten abschluessig, in den kurzen stumpf winkeligen Fluegel uebergehend. Die kurze Schlosslienie macht der Achse einen spitzigen Winkel, und vom Winkel strahlen starke, convexe Rippen aus, welche nach hinten allmaelig schmaeler werden. Ihre Zwischenraeume sind eben so breit und flach-concav. Bei einem Exemplare sieht man vor dem Wirbel leistenfoermige Zaehne, und bei einem andern sind Spuren zahlreicher concentrischer Streifen bemerklich.

The figure published by Goldfuss leaves no doubt of the distinctness of *Byssonychia carinata* from *Byssonychia radiata*. The description and the figure together indicate a species of the *Byssonychia praecursa* and *Byssonychia richmondensis* type. Considering the fact that the former species was described from the Lorraine of New York and that the latter is a Richmond form, the presumptive evidence might be considered at first as in favor of *Byssonychia praecursa*. According to Ulrich, the number of radiating plications in *Byssonychia praecursa* varies from 38 to 42, while those of *Bysonychia richmondensis* number not less than 50. It is practically certain that the number of plications indicated by the figure of *Byssonychia carinata* published by Goldfuss is too small. In *Byssonychia praecursa* the anterior face is not as strongly flattened and the beak is more rounded than in *Byssonychia richmondensis*. These also are features apparently indicated by the figure of *B. carinata*. As regards the locality

cited by Goldfuss, Lewistown, in Oneida-Country, this probably should read Lewistown, Ontario Lake. In that event, it may be worth while noting that forms resembling *Byssonychia richmondensis* occur in the Richmond north of Lake Ontario, as far east as Streetsville, a short distance west of Toronto.

The specimen figured by Hall (*Paleontology of New York, vol. I, pl. 80, Figs. 5a, 5b*) is stated by Whitfield and Hovey to have been found loose on the south side of Lake Ontario. It gives indications of the presence of 30 plications, and formerly must have had at least 2 more, the full number not being known. Another specimen, not figured, but preserved in the Hall collection in the American Museum of Natural History, and evidently collected after the publication of vol. I, presents the outline and the broad, flat anterior face of *Byssonychia richmondensis*, and almost certainly belongs to that species. The anterior umbonal angle is abrupt. The number of plications preserved is 33, and the original number must have equalled 37. It is regarded as belonging to the same species as the form figured by Hall.

The result of these studies has been to definitely determine that *Byssonychia carinata*, of Goldfuss, belongs to the group of species having a flattened anterior face, but an actual examination of the type must be made to definitely determine the identity or nonidentity of this species with *Byssonychia praecursa* or *B. richmondensis*. Under these circumstances, it seems best to discard the use of Goldfuss's name, until more is known regarding his type.

A Taeniaster from the Richmond of Meaford, Ontario

Taeniaster meafordensis, sp. nov.

(*Plate IV, Figs. 5, 6, 7*)

Central disc 7 to 8 mm. in diameter. Rays 11 to 15 mm. in length. Total spread of the animal, including the rays, therefore about 35 mm. Rays 2 mm. wide at the margin of the central disc, tapering rather gradually toward the extremities.

Ambulacral groove occupied by two rows of ambulacral plates, about 8 in a length of 5 mm. Those on opposite sides of the median line alternate with each other, the adjoining margins being slightly concave, so that two adjoining ends on one side of the median line fit against the concave middle of the plate on the

other side. The lateral distal quarter of the ambulacral plate area is strongly depressed as though for the passage of the tube feet. This gives the ambulacral plates on the right side the appearance of a short stumpy L, while those on the left side have the same appearance with the direction of the foot of the L inverted. This feature is well exhibited along that part of the ray traversing the central disc, and along half the length of the free part of the ray. Farther out, the ambulacral plates become more narrow and the L form is less in evidence.

Laterally, the ambulacral plates are bordered by the adumbulacral plates. Each ambulacral plate begins at the extremity of the base of L-like ambulacral plate and extends beyond the base of the next distal plate, successive adambulacral plates overlapping like a series of tiles, concave on the inner side and convex outside. A single narrow rotund spine is attached to each adumbulacral plate, the point of attachment being near the distal margin of the plate somewhere near its median axis. If any other plates are present on the ventral side, these have not been detected. Moreover, the presence of actual passages for the tube feet has not been seen, though inferred from the visible part of the ambulacral plates.

On the dorsal side, the rays are strongly convex. There are two rows of ossicles, the two rows alternating. These ossicles are transversely convex, and adjoin laterally a series of distally overlapping plates which are assumed to be the adumbulacral plates already described; toward their distal margins each of these adumbulacral plates bears a single rotund spine about as long as the supporting plate itself.

The entire dorsal surface of the rays and of the central disc appears to have been covered with a thin integument which was minutely granular. Some of these granules are larger and may have supported minute spines or other appendages. Minute spines probably were numerous also on the interambulacral parts on the ventral side of the disc, but in the present state of preservation of the specimens, the presence of these spines can not be determined definitely.

Only 5 oral ossicles can be detected, one at each interambulacral angle; however, since they extend distally like the sides of the letter V into the adambulacral rows of plates, it may be assumed that they are homologous to the 5 pairs of plates found in typical

Taeniaster. At their proximal terminations these oral ossicles are blunt and strongly elevated.

Only the more conspicuous elements of structure can be detected in the specimens at hand. Therefore there is opportunity for glaring misinterpretations of structure on the part of the present writer.

Locality. About 220 feet above Lake Huron, on Workman's creek, three miles southeast of Meaford, Canada, in the Richmond group.

Compared with *Taeniaster elegans*, Miller, from the Waynesville member of the Richmond, in Ohio, the adumbulacral plates are longer, distinctly overlapping, and bear correspondingly shorter spines; the oral ossicles are more blunt and more conspicuously elevated at their proximal terminations; nevertheless it is with this species that the Meaford form is most closely related.

Taeniaster miamiensis, Miller, from the Waynesville member in Ohio, is figured as having more strongly overlapping adumbulacral plates, with shorter spines, two being figured to a plate; the L-shaped form of the ambulacral plates is not indicated although it probably was present; the oral ossicles are figured as longer and with less divergent posterior terminations.

It is evident that both *Taeniaster elegans* and *Taeniaster miamiensis* must be republished before these species can be made available for purposes of correlating other forms believed to belong to approximately the same stratigraphical horizons. The types of both forms are now in the possession of the U. S. National Museum, but were in the exhibition cases at the time of my visit, from which it was difficult to remove them within a short time owing to the heavy plate glass front. Under these circumstances the examination of the specimens proved not sufficiently illuminating. While the Meaford specimens are regarded as indicating the Waynesville age of the strata in question, the actual identity of these specimens with *Taeniaster elegans* or *Taeniaster miamiensis* could not be demonstrated.

EXPLANATION OF PLATES

PLATE I

Fig. 1. Whitella securiformis. Riviere des Hurons, province of Quebec. Type. Geological Survey of Canada.

Fig. 2. Whitella complanata. Riviere des Hurons, province of Quebec. Type. Geological Survey of Canada.

Fig. 3. Whitella goniumbonata. Riviere des Hurons, province of Quebec. Geological Survey of Canada.

Fig. 4. Modiolopsis postplicata. Riviere des Hurons, province of Quebec. Geological Survey of Canada.

Fig. 5. Orthodesma approximatum. Chambly village, province of Quebec. Geological Survey of Canada.

Fig. 6. Clidophorus praevolutus. Two specimens, not types. Riviere des Hurons. Geological Survey of Canada.

Fig. 7. Modiolodon poststriatus. One mile west of Vars, province of Quebec. Geological Survey of Canada.

Fig. 8. Pholadomorpha chambliensis. Chambly village, province of Quebec. Geological Survey of Canada, No. 2069.

Fig. 9. Cymatonota lenior. Riviere des Hurons, province of Quebec. Geological Survey of Canada.

Fig. 10. Caritodens demissa, Conrad. Riviere des Hurons, province of Quebec The terminations of the anterior ear and posterior wing are omitted. Geological Survey of Canada.

Fig. 11. Rhytimya oehana, Ulrich. Chambly village, province of Quebec. Geological Survey of Canada.

Fig. 12. Clidophorus praevolutus. Chambly village, province of Quebec. Geological Survey of Canada, No. 2079.

Fig. 13. Clidophorus sp. Rome, New York. From collections of the New York State Museum at Albany, No. R–1232.

Fig. 14. Cymatonota pholadis, Hall. Chambly village, province of Quebec. Geological Survey of Canada.

Fig. 15. Orthodesma prolatum. Beach below Becanceur river, province of Quebec. Geological Survey of Canada, No. 2144.

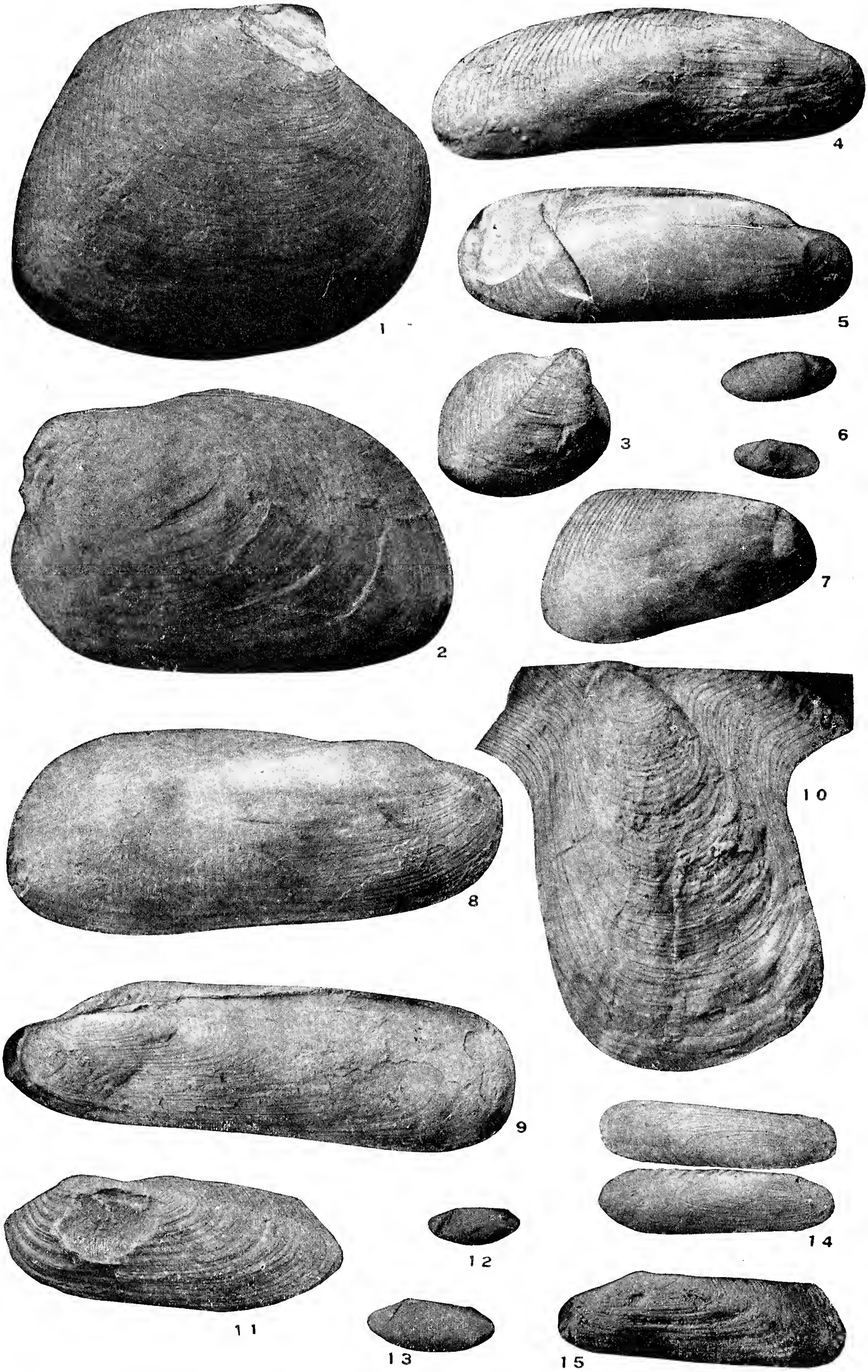
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PLATE II

Fig. 1. Pterotheca pentagona. Chambly village, province of Quebec. Geological Survey of Canada, No. 2155.

Fig. 2. Pterotheca pentagona. Nicolet River, southwest of Ste. Monique, province of Quebec. Geological Survey of Canada.

Fig. 3. Pterotheca cf. attenuata, Hall. Western shore of Cloche peninsula, province of Ontario. Geological Survey of Canada. Lower Lowville red clay shales.

Fig. 4. Strophomena planumbona, variety. *A*, Chambly village, No. 8404. *B*, Riviere des Hurons, No. 8405. Both from the province of Quebec. Geological Survey of Canada.

Fig. 5. Archinacella clochensis. Western shore of Cloche peninsula, province of Ontario. Geological Survey of Canada. Lower Lowville red clay shales.

Fig. 6. Cyrtodonta clochensis. Western shore of Cloche peninsula, province of Ontario. Geological Survey of Canada. Lower Lowville red clay shales.

Fig. 7. Rafinesquina mucronata. A mile northwest of Vars, province of Quebec Not the types. 7 A, No. 8432; 7 B, No. 8432 a; Victoria Memorial Museum, Ottawa, Canada.

Fig. 8. Lophospira beatrice. Riviere des Hurons, province of Quebec. Types. Geological Survey of Canada.

Fig. 9. Psiloconcha borealis. *A*, *B*, Riviere des Hurons; *C*, Nicolet River, southwest of Ste. Monique; all from province of Quebec. *B* is selected as type. Geological Survey of Canada. *A*, No. 2087. *B*, No. 8411. *C*, No. 8412.

Fig. 10. Colpomya pusilla. Chambly village, province of Quebec. Not the type.

Fig. 11. Lingula clochensis. *A*, pedicel valve, No. 8403; *B*, brachial valve, No. 8403*a*. Western margin of Cloche peninsula, province of Ontario. Geological Survey of Canada. Lower Lowville red clay shales.

Fig. 12. Cuneamya brevior. Riviere des Hurons, province of Quebec. Geological Survey of Canada.

Fig. 13. Technophorus quincuncialis. Chambly village, province of Quebec. Geological Survey of Canada.

Fig. 14. Pholadomorpha divaricata. Riviere des Hurons, province of Quebec. Geological Survey of Canada, No. 2071.

Fig. 15. Psiloconcha subovalis, Ulrich. Riviere des Hurons, province of Quebec. Geological Survey of Canada.

Fig. 16. Pholadomorpha pholadiformis, Hall. Two miles northeast of Gore Bay, along the shore, Manitoulin island, province of Ontario. Geological Survey of Canada.

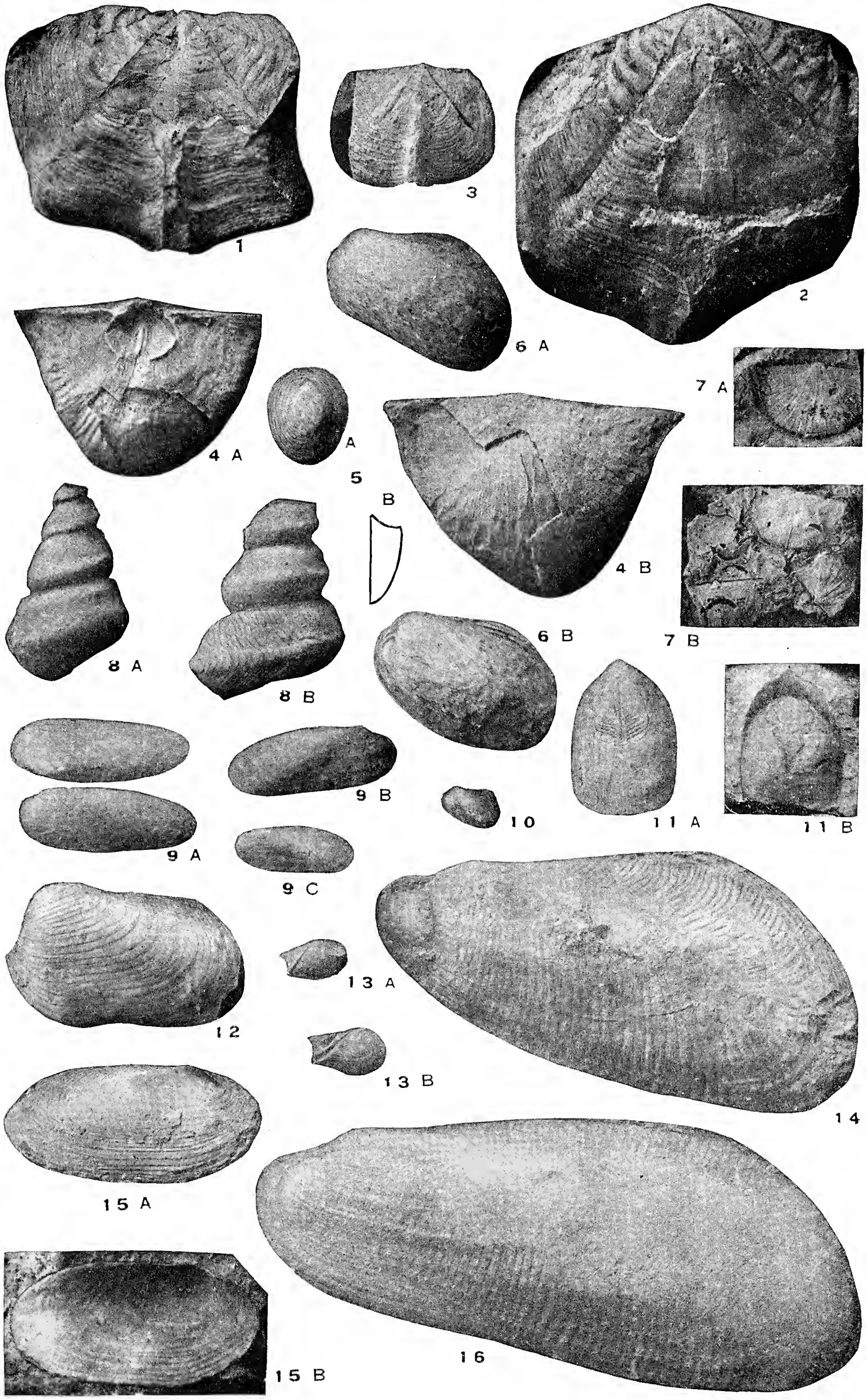
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PLATE III

Fig. 1. Modiolopsis modiolaris, Hall. Half a mile east of Worthville, New York, along a creek north of the pike.

Fig. 2. Rafinesquina nasuta, Conrad. Pedicel valves. From a ferruginous boulder containing *Trinucleus*, a short distance west of the railroad bridge, a mile east of Pulaski, New York.

Fig. 3. Archinacella pulaskiensis. Pulaski, New York, west of the railroad bridge, one mile east of New York.

Fig. 4. Colpomya pusilla. In *Trinucleus* bed, west of railroad bridge, one mile east of Pulaski, New York.

Fig. 5. Orthodesma nasutum, Conrad. Two and a half miles east of Worthville, New York.

Fig. 6. Orthodesma pulaskiensis. Immediately below railroad bridge, one mile east of Pulaski, New York.

Fig. 7. Cymatonota pholadis, Conrad. Near head of Gulf west of Turin, New York, along road leading southwest up the hill toward a school house.

Fig. 8. Ctenodonta lorrainensis. Half way between Lorraine and Worthville, New York, where the pike crosses a creek. *A*, interior cast; *B*, interior cast of the opposite valve, inverted, with beak down.

Fig. 9. Glyptorthis crispata, Emmons. Half way between Lorraine and Worthville, New York, where the pike crosses a creek.

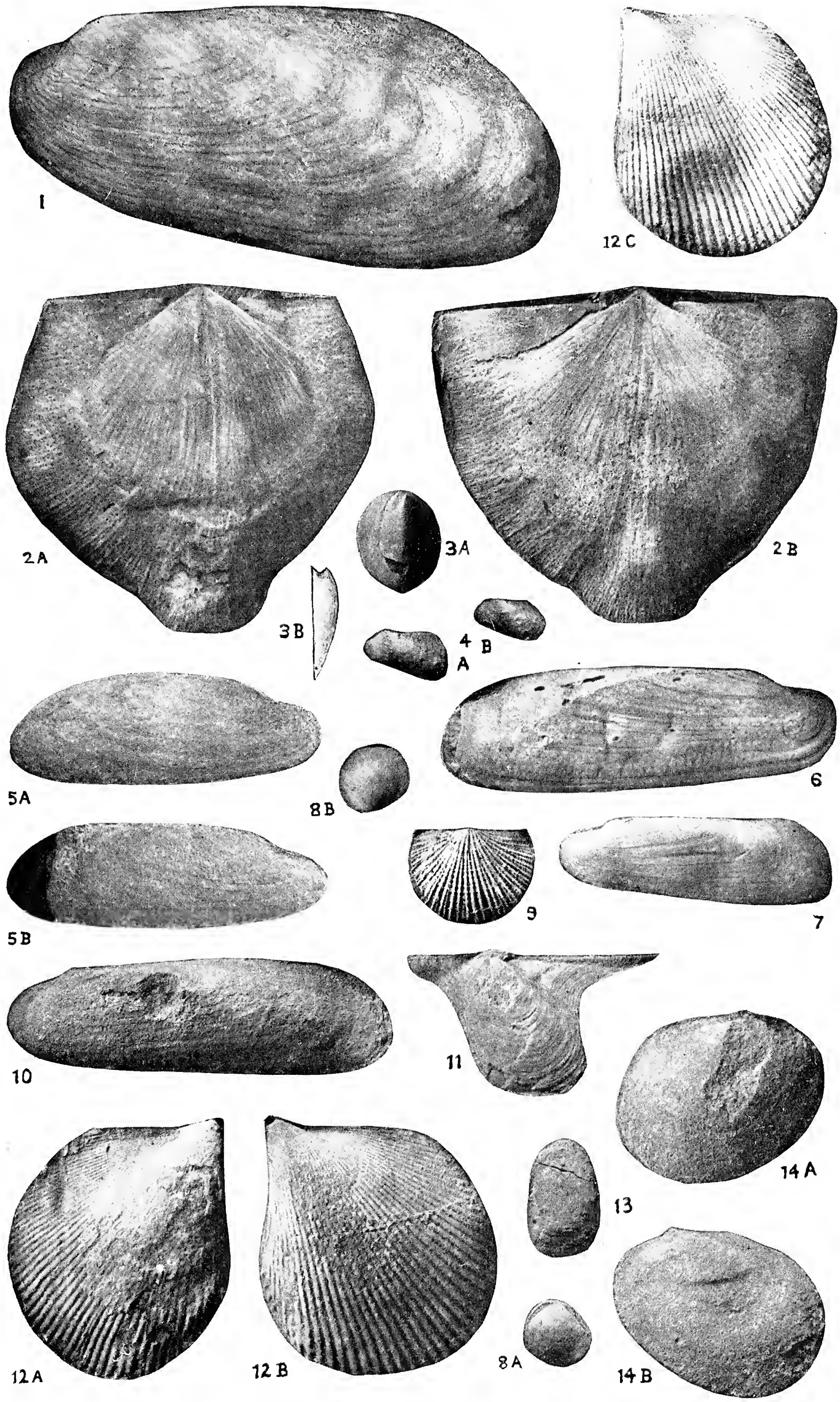
Fig. 10. Orthodesma sp. At the cross roads one mile south of Barnes Corners, New York. See under *Orthodesma pulaskiensis*.

Fig. 11. Pterinea (Caritodens) demissa, Conrad. Young specimen. Chambly village, on the Richelieu river, Province of Quebec. Geological Survey of Canada. No. 8433, Victoria Memorial Museum, Ottawa. Canada.

Fig. 12. Byssonychia radiata, Hall. *A*, Form with 55 plications; *B*, with 47 plications. *C*, with 48 plications; type of species, the original of Fig. 4*a*, on plate 80, vol. I, *Paleontology of New York*. Pulaski, New York.

Fig. 13. Lingula sp. Belonging to the *Lingula procteri* group. At the *Trinucleus* horizon, a short distance west of the railroad bridge, one mile east of Pulaski, New York. See under *Lingula rectilateralis*, Emmons.

Fig. 14. Ischyrodonta *curta*, Conrad. Bennett Bridge, one mile down stream from Salmon River Falls, New York.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8 A
12 A
12 B
14 B

PLATE IV

Fig. 1. Proetus chambliensis. *A*, *B*, *C*, complete individuals, the latter partially exposed, exhibiting the genal spines; the glabella is best preserved in *A*. The neck ring is best seen in *D*, and *E*. The pygidium is well shown by *E*, *F*, *G*, and *H*. The curvature of the extremities of the pleural segments best seen in *G*. Rock fragment collected at Chambly village, a short distance south of the dam across the Richelieu River, in the province of Quebec. Preserved in the Victoria Memorial Museum, Ottawa, Canada, No. 8435. Figure magnified two diameters.

Fig. 2. C. Rafinesquina nasuta, Conrad. Cast of interior of pedicel valve, from large rock containing Trinucleus, Modiolopsis modiolaris, and numerous other Lorraine fossils, a short distance west of the railroad bridge at Pulaski, New York.

Fig. 3. Archinacella pulaskiensis. *C*, View from above. *D*, a lateral view. From the Trinucleus horizon several hundred yards west of the railroad bridge, at Pulaski, New York.

Fig. 4. Pasceolus globosus, Billings. Specimen showing concave plates with radiating grooves. A short distance below the Fulton layer, in the Point Pleasant limestone section, at the quarry west of Point Pleasant, Ohio.

Fig. 5. Taeniaster meafordensis. *A*, *B*, two specimens showing the oral side. *C*, specimen showing the aboral side; only the lower arm in the left side, as figured, is well exposed.

Fig. 6. Taeniaster meafordensis. *D*, oral side, poorly preserved. *E*, *F*, aboral side, with the surface of one of the arms, in *F*, well exposed.

Fig. 7. Taeniaster meafordensis. *G*, a specimen with the arms bent back. Specimens in this attitude were common in the rocks layer from which the various fragments here illustrated were obtained. Hundreds of individuals were crowded closely together. Richmond group, along Workman creek, three miles southeast of Meaford, Ontario, Canada.

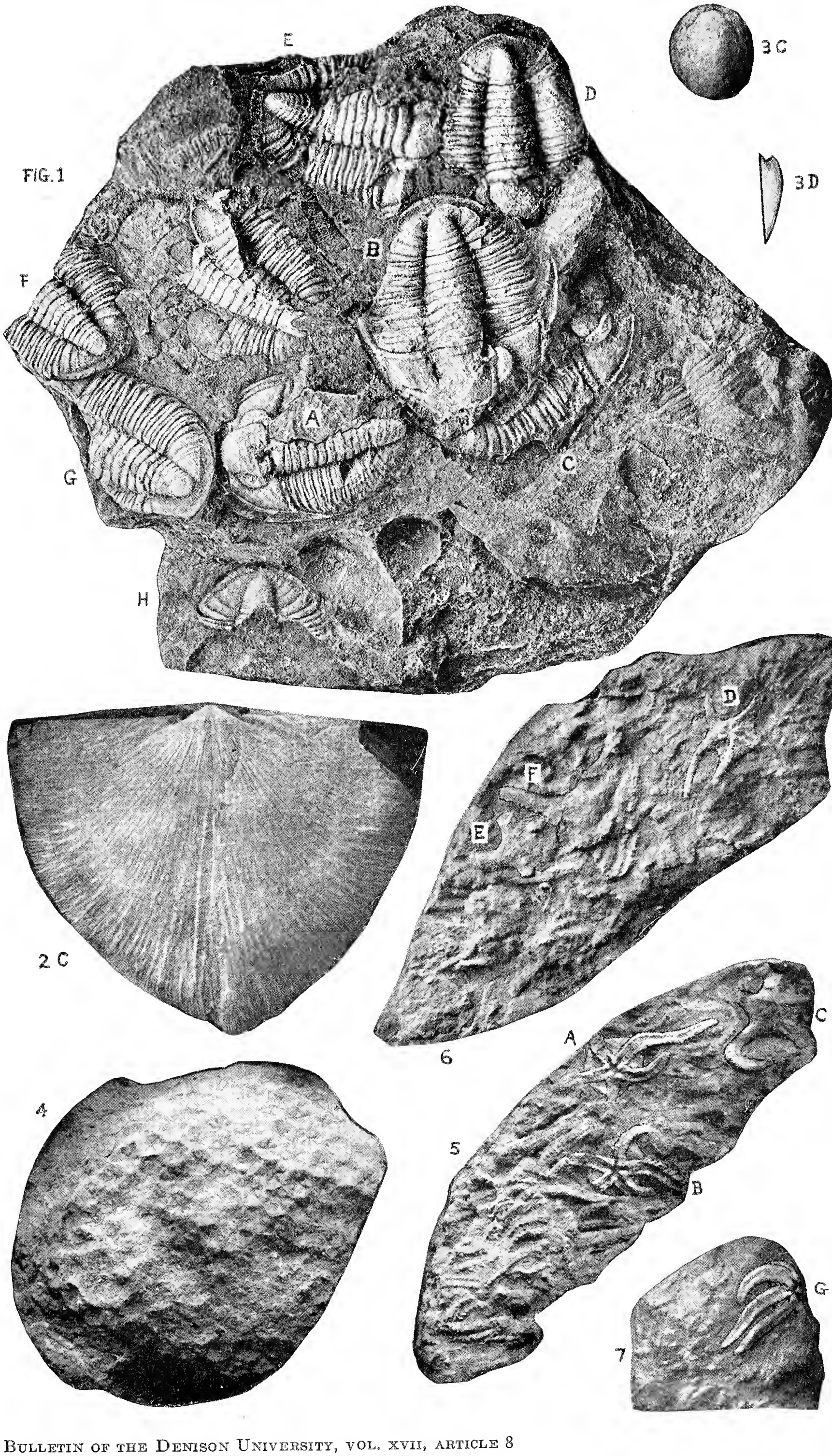

E
3 C
D
FIG. 1
3 D
B
F
A
G
C
H
D
F
E
2 C
6
A
C
4
5
B
G
7

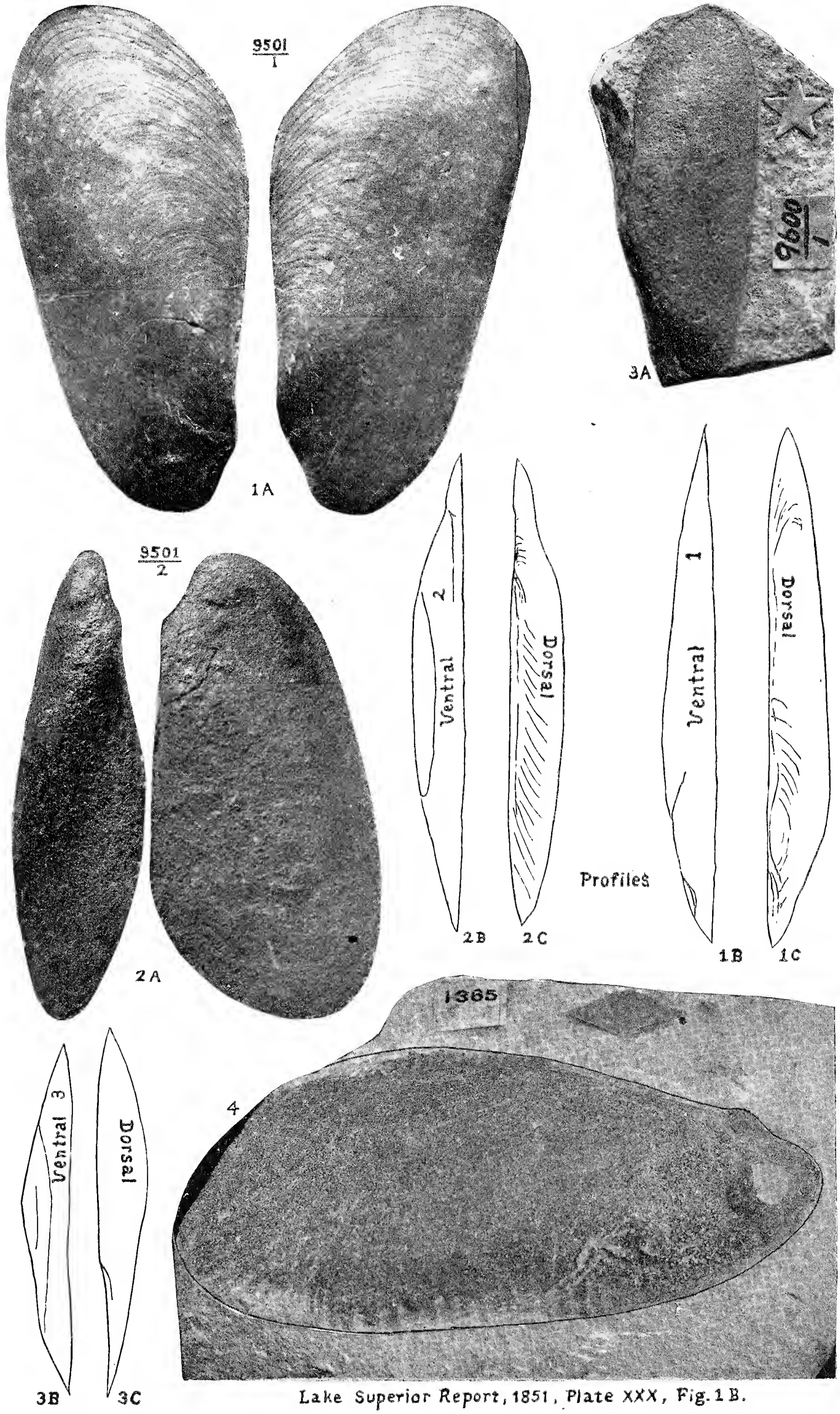
PLATE V

Fig. 1. Modiolopsis modiolaris, Hall. *A*, two valves, as seen on a single slab; original of Fig. 1*a*, on plate 81, *Paleontology of New York*, vol. I; preserved in the New York State Museum at Albany, New York, as No. 9501–1. In a sandy, somewhat micaceous shale at Rome, New York. *B, C*, ventral and dorsal profiles, prepared by Dr. Ruedemann, but not intended for publication.

Fig. 2. Modiolopsis modiolaris, Hall. *A*, two valves, as seen on a single slab; original of Fig. 1*b*, on plate 81, *Paleontology of New York*, vol. I; No. 9501–2 in New York State Museum. In a gray sandstone from Rome, New York. *B, C*, ventral and dorsal profiles, sketched by Dr. Ruedemann.

Fig. 3. Orthodesma nasutum, Conrad. *A*, left valve, injured along the upper margin anterior to the beak; outline here incorrect; original of Fig. 2, plate 81, *N. Y. Pal.* I; No. 9600–1, in N. Y. State Museum. Labeled as coming from Lorraine, Jefferson county, New York. *B, C*, ventral and dorsal profiles, sketched by Dr. Ruedemann.

Fig. 4. Pholadomorpha pholadiformis, Hall. Original of Fig. 1*b*, on plate XXX, accompanying the original description in Report on the Geology of the Lake Superior Land District, by Foster and Whitney, in 1851. In type series 1365, preserved in the American Museum of Natural History, in New York city. Specimen poorly preserved. Outline, as interpreted by the writer, indicated in ink. The elevation above the anterior muscular scar is the beak, near which the specimen is injured by crushing.



Lake Superior Report, 1851, Plate XXX, Fig. 1B.

A COMPARATIVE STUDY OF CIRCULAR AND RECTANGULAR IMHOFF TANKS[1]

THEODORE SEDGWICK JOHNSON

INTRODUCTION

No other development of sanitary engineering has taken place that has aroused so much interest as the Imhoff, two-story sedimentation tank. Installed first in the Emscher district in Ger-

[1] Thesis presented to Ohio State University for degree of C.E., June, 1913.

many in 1906, its use in America is comparatively new, there probably being to date no more than one score of installations. Experiments at Philadelphia and Chicago have proved favorable, and at least one large city—Atlanta, Georgia—has installed them as adjuncts to disposal plants.

This thesis attempts an economic design of two such tanks as applied to the disposal plant of a small community, and makes comparisons of rectangular and circular tank, with special regard to costs and clarification efficiency.

Historical Sketch of Development of Clarification Methods

At this point a brief digression into the history of the Imhoff tank may be of value.

In 1810 the water-closet was reinvented and its use in the cities of the Continent and in England rapidly increased. Until 1815 the drains of London, as they were called, were not intended to carry any but surface wastes, and it was not until that time that the members of English communities realized the need of sanitary precautions and ordered all water-closets to be connected to the drains or sewers, as they really began to be.

This led, of course, in the thickly populated districts of Europe, to a fearful state of river pollution, which continued until 1858 in England, when, as a result of a Sanitary Commission's report, further pollution of the rivers was prevented. In Germany the same conditions were generally true, finding their worst condition in the Emscher district. This district was placed under the control of the Emschergenossenschaft in 1906, though steps had been taken to improve the wretched sanitary conditions of the valley as early as 1889.

When river dilution was prohibited, various stages of disposal processes were gone through, tending chiefly in the direction of purification by infiltration. In any of the early disposal processes, serious trouble was caused by the suspended solid material, partly material and partly organic in nature. To remove this suspended matter, various types of sedimentation processes were resorted to. Sedimentation may be either plain or chemical, and both types may be further classified as grit chambers and true sedimentation tanks. Again, the latter may be re-classi-

fied, according to the manner of disposal of the sludge or settled solid matter. If the sludge remains in the bottom of the tanks until partly liquiefied by bacterial action, the tank becomes a septic tank.

H. W. Clark, at the Lawrence Experiment Station, under the direction of the Massachusetts State Board of Health, in 1899 suggested the idea of a separate compartment for the settled out portions into which they could be occasionally flushed for further digestion and bacterial action, and in accordance with this idea a tank was constructed in November, 1899.

In England, Dr. W. O. Travis and his assistants, acting upon the favorable results of the Lawrence experiments, developed a type of hydrolytic or septic tank, which they patented and began to use in service in 1903. The improvement over the Lawrence idea lies in the fact that both compartments are parts of the same tank.

In the work of the Emschergenossenschaft, under the direction of Dr. Karl Imhoff and Mr. Chas. Saville, the Travis hydrolytic tank was experimented on, beginning in 1906, and modifications were soon made, which had for their specific purpose the prevention of any disturbance of the settled out solids, by the sewage flow through the sedimentation chamber above. Continued experiments have been and are being made, looking toward the improvement of the tank treatment.

Briefly, the advantage of the tank lies in the stability of the clarified sewage, and the ease with which it can be subjected to later purification process; the freedom from objectionable odors; the absence of any dissolved oxygen in the digested sludge; the ease of manipulation and favorable character of the sludge, as compared with the sludge from the ordinary single story septic tank. The tank will be found to be more expensive to build, but gives evidences of operating results, which are worth the added expense.

The Imhoff tanks are built in three distinct types: (1) the radial flow tanks; (2) horizontal flow tanks, with rectangular digestion chambers, and (3) horizontal flow tanks, with circular digestion chambers. This thesis will discuss the comparative values of the first two types.

Data for Design

For the purpose of this thesis, the town of Granville, Licking County, is chosen, and the design is made as of one part of an entire sewer system and disposal plant.

Locality, Granville, Ohio. Granville is a small residence community, the seat of Denison University, and has a resident population of about 1300, which is increased to probably 2000 as a maximum during sessions of the University. The soil is of gravel and sand, characterized as glacial drift, and has been favorable for the long use of cess-pools.

The town is situated in the watershed of Raccoon Creek, a tributary to the Licking River, into which stream it empties at Newark, approximately seven miles away. The proximity of Newark, through part of which Raccoon Creek flows, together with the small flow of the stream at dry seasons, precludes the possibility of emptying untreated sewage directly into the stream.

Some method of purification will then be necessary. This thesis assumes the installation of a screen chamber, settling tank and intermittent sand filters, and will deal only with the settling tank, designing it, however, as a part of this particular disposal plant.

Tributary population. As stated above, the resident population is about 1300, and the present maximum about 2000. It will be some time after the introduction of the new system before this population will be tributary to the system. The town is not a manufacturing or industrial center, and, with the exception of the University, cannot be expected to have any great increase in population, and it would seem that at the end of five years a maximum population of 2500 and at the end of ten years a population of 3000 would be a generous estimate. The design will be based, therefore, on a population of 2500. Another factor that would make this figure a conservative one is the probability of important changes in methods of sewage disposal that may make changes necessary at a later time.

Character of sewage. The sewage will be that of a residence community, as almost no industrial wastes are produced in Granville. The sewer system is of the separate type, so no large amount of rainfall will reach the sewers. The sewers will be laid in gravel deposits, and in almost no case will the grade of

the invert be below ground-water level. This sewage, therefore, will be almost entirely domestic in composition, and will be very much diluted at first. Authorities differ in the amount of sewage per capita and the variations in it.

Amount of sewage. In the Emscher district the following values obtain: Recklinghausen has a daily flow of 83 gallons, Essen-North about 90, and two smaller towns 125 to 145 gallons per capita daily. Kinnicutt, Winslow and Pratt, in statistics of English towns, show values ranging from 35 to 95, and state that the average for English towns is 49.1 gallons per capita, for large towns about 100. In the Emscher District the maximum hourly flow is about one-eighteenth of the daily. Raikes says in English practice the minimum is one-half the average and the maximum twice the average.

Ogden says the maximum is 50 per cent more than the mean. He advocates also an indirect method, by finding the water consumption, taking 75 per cent of this for the average, and adding 100 per cent to the latter for a maximum. Fuller, in tables from Massachusetts State Board of Health report for Gardner, Massachhsetts, in 1898, and in reports for Columbus, shows that the maximum rate is about 125 per cent of the average.

For the purposes of this design, a flow of 75 gallons per capita daily and a maximum flow of one and one-half times the mean will be assumed.

This means, then, a flow of 2500 $\times$ 75 gallons or 187,500 gallons per day, or an average hourly flow of 7810 gallons. Assuming a maximum flow of one and one-half times the mean, we would have to provide for a maximum hourly flow of 11,715 gallons.

Detention period. After obtaining the quantity of sewage to be treated, the next factor in the design is the determination of the best period of detention or the flowing through time.

Opinion and practice differ in regard to what may properly be called solids capable of removal by sedimentation. The fundamental proposition of sedimentation is that every solid particle will settle in water at a velocity depending upon its size and weight and upon the viscosity of water. It is also found[2] to depend upon the area of the bottom surface exposed to receive

[2] Hazen's *Transactions of A. S. C. E.*, vol. liii, p. 45.

sediment. Travis used this idea by suspending many plates in the sedimentation basin.

A certain portion, therefore, of the solid content of sewage will settle to the bottom of the Imhoff tank in a relatively short time, while a larger portion will settle in three hours. After that, no appreciable increase in amount of sediment will take place, and the amount deposited at the end of six or eight hours will be little larger than that found at the end of three hours. Dr. Imhoff, in discussing this question, divides solids in sewage in four classes:

1. Settling solids, or those heavier portions which would settle out of still sewage in two hours' time.
2. Finely divided matter, or matter which would remain as residue after filtration through paper.
3. Colloidal matter, still finer, which would pass the filter paper but remain on a dialyzing membrane.
4. Matter that is in true solution.

It is only the solids in Class 1 that can be affected by the operation of plain sedimentation, though, of course, the length of time allowed—two hours—or the division line between classes one and two, might be uncertain. Dr. Imhoff claims, however that to rightly judge the efficiency of sedimentation processes, only the matter that comes under Class 1 should be included, as those capable of deposition. Any currents or velocity of flow in the tank would tend to decrease the amount of matter that would settle out of a given sewage, and efficiencies can therefore rightly be calculated on that basis. That means, then, that in Imhoff tanks a period of detention in excess of two hours is unnecessary. In existing plants the detention periods are as follows:

Plant	*Time*
Atlanta, Georgia	3 hours
Winters, California	3 hours
Philadelphia, Pennsylvania (experimental plant)	1 hour
Philadelphia, Pennsylvania (experimental plant) (deeper tank)	2 hours
Erie, Pennsylvania	40 mins.
Recklinghausen, Germany	1 hour
Essen-North	1 hour

From the character of the sewage to be treated in this installation, an average period of two hours will be assumed. For the

average flow, then, this means a capacity in the settling chamber of 15,620 gallons or a flowing-through time for maximum flow of $\frac{15,620}{11,715}$, or one hour and twenty minutes.

For a considerable period of time after the inception of the disposal process, it is probable that the period of detention will be much longer than the above figures.

In designing tanks, care must be taken to see that the flow is evenly distributed, that no "dead" places or places of low velocity occur.

In old-style, single-story, sedimentation tanks, the velocity was an important factor in design, as affecting the deposition of material. The effect of excessive velocity in the two-story tank is minimized by the fact that the solid part or sludge is removed from the disturbing effect of velocities on the liquid.

The velocities of flow in Imhoff tanks operated in the Emscher District have been studied, and Mr. Chas. Saville, formerly of the Emschergenossenschaft, recommends 0.20 of an inch per second, with 0.50 inch per second as a maximum, for satisfactory results.

Volume of sedimentation chamber. Knowing the value of average and maximum flows and the best detention period determines the volume or capacity of the settling chamber and the arrangement of baffles in the chamber will be such as to keep the velocity and mixing in proper condition.

Volume of sludge chamber. The next step in design is to determine the capacity of the sludge or digestion chamber.

The capacity of the sludge chamber will depend upon the character and amount of suspended matter. In the deeper tanks, the sludge, being under greater pressure, is much more compact than in the case of the shallow tank. The patentees of the tank recommend that the sludge chamber for shallow tanks be made 50 per cent greater than in the deep tank.

In large tanks some sludge may be drawn off every month, but in the smaller tanks the sludge should be kept nearly to the slots. Not all of the sludge should be removed at any one time. At the end of summer, the sludge is usually drawn off, to receive the winter's accumulation of sludge. The usual storage capacity is six months. In the plant at Winters, California, the sludge-chamber capacity was calculated on the basis of 0.007 cubic foot of sludge per capita per day.

Philadelphia experiments show 0.9 cubic yard per million gallon, or at a rate of 75 gallons per capita, a deposition of sludge at the rate of 0.002 cubic foot per capita per day.

Chicago experiments show 2 cubic yards during the summer and fall of 1910 and 0.93 cubic yards per 1,000,000 gallons for five months.

At Recklinghausen, 1.65 cubic yards, at Bochum, 2.1 and at Essen-N-W, 1.39. The last three values deal, of course, with strong sewage. Allen advises a sludge storage capacity to provide for a mean between the amount of fresh sludge and the final volume of treated Imhoff tank sludge. Allen states by formula the capacity $C = 5250\ PD$, where P is population, C capacity in cubic feet and D the day's retention of sludge.

Imhoff gives for Bochum (combined system) a value of 0.007 cubic foot per capita daily—the figure used in the Winters, California, installation, and says it would be half that much for separate system, or 0.0035. On these assumptions, John H. Gregory, for the Metropolitan Sewerage Commission of New York, prepared a table,[3] which gives for a daily sewage flow of 75 gallons per capita a volume of sludge of 1.7 cubic yards per 1,000,000 gallons.

Tabulating the various estimates:

	Cubic feet per capita daily
Winters, California	0.007
Philadelphia, Pennsylvania	0.002
Chicago, Illinois	0.002
Recklinghausen, Germany	0.0036
Bochum	0.0045
Essen, N-W	0.0031
Gregory (Metropolitan Sewage Commission)	0.0038
Pacific Flush Tank Company pamphlet	0.0033
Allen, Hazen (Amer. C. E.'s Pocket Book)	0.0022 to 0.0044

With these comparative figures before us, it seems reasonable to adopt a figure of 0.0035 cubic foot per capita daily, as the rate of deposition of sludge in the digestion chamber.

[3] Allen, *Sewage Sludge Treatment in the United States*, pp. 229.

Design of Tanks

Size of sedimentation and sludge chambers. 15,620 gallon capacity is equivalent to $\frac{15,620}{7.48} = 2085$ cubic feet ($7.48 =$ the number of liquid gallons in 1 cubic foot). This is the required capacity of the sedimentation chamber.

For the assumed population of 2500 and a storage capacity for six months' sludge (required on account of winter storage of sludge) and a rate of 0.0035 cubic foot per capita per day, there will be required $2500 \times 0.0035 \times 6 \times 30 = 1575$ cubic feet, or 42 per cent of the total volume. With a storage capacity in the sedimentation chamber of 2610 cubic feet (calculated on the basis of two and one-half hours detention period) this would be 36.5 per cent of the total volume.

In view of the small size and necessary small depth of the tanks, this is the ratio of capacities of the sedimentation and sludge digestion chambers, though larger than usually specified, the ratio for the Proctor Creek plant in Atlanta, Georgia, being 25 per cent.

Stresses in tank walls. In calculating the stresses, for the purpose of detailed design, two kinds will develop.

When the tank is empty, earth pressure will act upon the walls inward, producing bending moments in one direction at the middle of one side of the rectangular tanks and in the opposite direction at the ends. In the circular tank compression will result in the entire ring.

As an alternative loading, the case may be considered where the tank is full of water, and because of slippage, earth contraction and bad construction, the backing has been removed far enough for flexure of the walls to take place, to develop flexural stresses of reverse signs in the rectangular tank and tensile stresses in the circular tank.

The sloping bottoms may be considered as any tank foundation and designed accordingly. At the points of connection with the vertical walls, stresses will be developed which are uncertain in amount and character, but will be provided for by connecting reinforcing steel.

The walls will be considered as slabs resting upon two vertical beams, and loaded uniformly along a horizontal strip. The two vertical beams may be either the end walls or intermediate beams

held apart at the top by a horizontal strut. The ends will be considered fixed and the same bending moment will be assumed at all corners. For a pressure P and width b and length l of the tank this negative bending moment will be found (by equating the moments from each side) to be $\frac{1}{2}p\ (b^2 - bl = l^2)$.

If the corners were hinges, the maximum bending moment would be $\frac{1}{8}pl^2$ in the center, but it is reduced by the negative bending moments produced by fixed ends. The value then becomes $\frac{1}{24}\ p\ (l^2 - 2\ bl - 2\ b^2)$ as the maximum on the side where l and b are the lengths of the sides. The pressure of the earth will be calculated from Rankine's formula

$$p = wh \frac{l + \sin \phi}{l - \sin \phi} \text{ where } w = 100 \text{ pounds cubic feet and } \phi = 30°.$$

The pressure of the water will be determined by the usual hydrostatic law, $p = wh$. This would mean an earth pressure of 533 pounds per square foot and 998.4 pounds per square foot for water or total pressures on a vertical strip 1 foot wide of 3600 pounds and 6739.2 pounds.

If the long walls of the tank should be supported in the middle, the design would change to the condition of a continuous beam of two equal spans with fixed ends and consequent negative bending moments at each end and over the center support.

In this case, the maximum positive moment would be $\frac{1}{24}\ wl^2$ and the maximum negative moment $\frac{1}{12}\ wl^2$. For the lower portion of the wall a great deal of the stresses will be taken to the sloping bottom, but it will be on the safe side to assume the wall as continuous over three supports. When the slab is reinforced in both directions, the analysis becomes more complex. For square slabs such as this would be, if not supported in the middle, the reinforcement would be equal in all directions. For rectangular slabs the relative amount of stress on the system parallel to the long side of the slab becomes less.

In the case of the side walls in the tank under consideration, if a beam is used to strengthen the slab in the center, they become oblong panels, while they remain approximately square if not so supported. This theoretical consideration cannot be of any effect in this case, because one side of the slab, i.e., the top, is unsupported.

The slab will therefore be designed as if composed of a series of horizontal beams, loaded uniformly by water pressure on the inside and earth pressure on the outside.

The pressures will be as follows:

Water $p = wh$ $w. = 62.4$ pounds cubic feet

	pounds square feet
4 feet depth	249.6
8 feet depth	499.2
12 feet depth	748.8
16 feet depth	998.4

Earth $p = wh \dfrac{l + \sin\phi}{l - \sin\phi}$ $w = 100$ pounds cubic feet $\phi = 30$

	pounds
4 feet depth	133.33
8 feet depth	366.66
12 feet depth	399.99
16 feet depth	533.32

When supported in the center of the long side, the slab has a span of 11 feet, and the beams are considered as fixed at both ends and the middle, so that a maximum negative moment of $\frac{1}{12}\,pl^2$ will be developed over the ends and a maximum positive moment of $\frac{1}{24}\,pl^2$ in the center.

The reversal of stress due to earth pressure, when the tank is empty, will have to be taken care of independently by reinforcement placed on the opposite sides of the wall from that required for water pressure. While theoretical analysis would show a possible reduction in total amount of steel, due to the presence of reinforcement in both sides of the slab, it would seem unwarranted in this analysis, because of the large number of indefinite factors in the cases.

Then for water pressure at the bottom $w = 998.4$ pounds square foot, $l = 11$, $l^2 = 121$, $M = \frac{1}{12} \times 998.4 \times 121 \times 12 = 120{,}768$ inch-pounds, $fs = 15{,}000$ pounds, $fc = 600$ pounds, $n = 15$

then

$$p = 0.0075$$
$$k = 0.375$$
$$j = 0.875$$
$$M_s = 15{,}000 \times 0.0075 \times 0.875 \times 12 \times d^2$$

or $$d = \sqrt{\frac{M_s}{f_s pjb}} = 10.1 \text{ inches.}$$

A 12 inch wall will then be assumed, and with $p = 0.0075$, there will be required 0.909 square inches of steel per foot width. This will require $\frac{3}{4}$ inch bars spaced 8 inches.

Vertical reinforcement will be $\frac{1}{2}$ inch rods, 18 inch centers, wired and clamped to horizontal rods.

The same thickness of wall will be assumed to the top, which is on the side of safety. For earth action inwards pressure would be 533.3 pounds square feet and $M = \frac{1}{12} \times 533.3 \times 121 \times 12^2 = 64{,}500$ inch-pounds.

To find d, assuming $b = 12$ inches, $d = \sqrt{\frac{M_s}{f_s pjb}}$, p and j would be as before. $d = 7.38$ inches and there would be required 0.0075×7.38 inches $\times 12$ inches or 0.675 inch per square foot width, which would require $\frac{5}{8}$ inch square rods spaced 7 inches and with proper reduction. At the 12 foot height, the moments are reduced 25 per cent, and $d = 76.5$ for water and 40.7 for earth. The corresponding values of d are 8.75 inches and 6.4 inches, while the steel required is

$$0.0075 \times 8.75 \times 12 = 0.79 \text{ square inch}$$
$$0.0075 \times 12 \times 6.4 \text{ inches} = 0.58 \text{ square inch}$$

This requires $\frac{3}{4}$ inch rods spaced 9 inches and $\frac{5}{8}$ inch rods spaced 8 inches. At the 8 feet height, 0.67 square inch and 0.50 square inch are required, which requires the

$\frac{3}{4}$ inch rods to be spaced 10 inches and the
$\frac{5}{8}$ inch rods to be spaced 9 inches.

For the last 4 feet both rods will be spaced 12 inches centers. In the case of the circular tank, the stresses will be determined in the same conditions. For pressure on the inside, the entire tank will be under tension, and would be designed in that way with vertical distribution. When empty (i.e., earth pressure acting) a uniform compression will be caused in the entire ring.

In the circular tank, the tensile stress at all points in a circular ring 1 foot high will be

$$t = \frac{18 \text{ feet} \times 998.4 \text{ pounds}}{2} = 8985.6 \text{ pounds.}$$

This would require, with steel at 16,000 pounds per square inch,

$\frac{8985.6}{16{,}000} = 0.56$ square inch per unit width. The thickness with

$p = 0.0075$ would then be

$$\frac{0.56}{0.0075} = \frac{74.7}{12} = 6\tfrac{1}{2} \text{ inches} \qquad \frac{74.7}{12} \text{ or } 6\tfrac{1}{2} \text{ inches approximately.}$$

Assuming a 7-inch wall, the earth pressure would produce a concrete stress

$$\frac{18 \text{ feet} \times 533.3}{2} - \frac{8985.6 \text{ pounds}}{84} = 107 \text{ pounds per square foot}$$

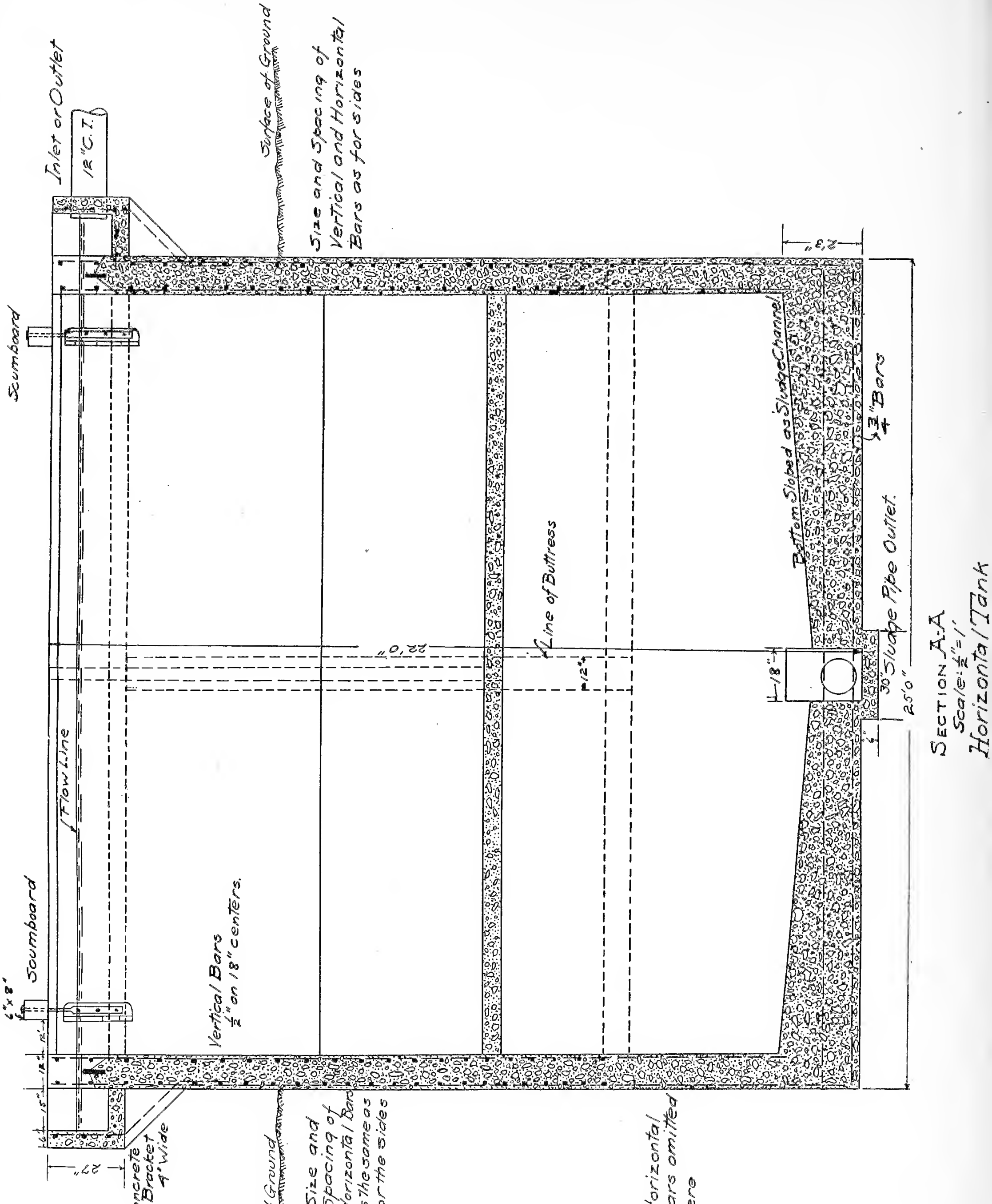
compression on the concrete.

While 7 inches would seem adequate, common practice in this type of wall is considerably heavier, so that a 12 inch wall will be used throughout.

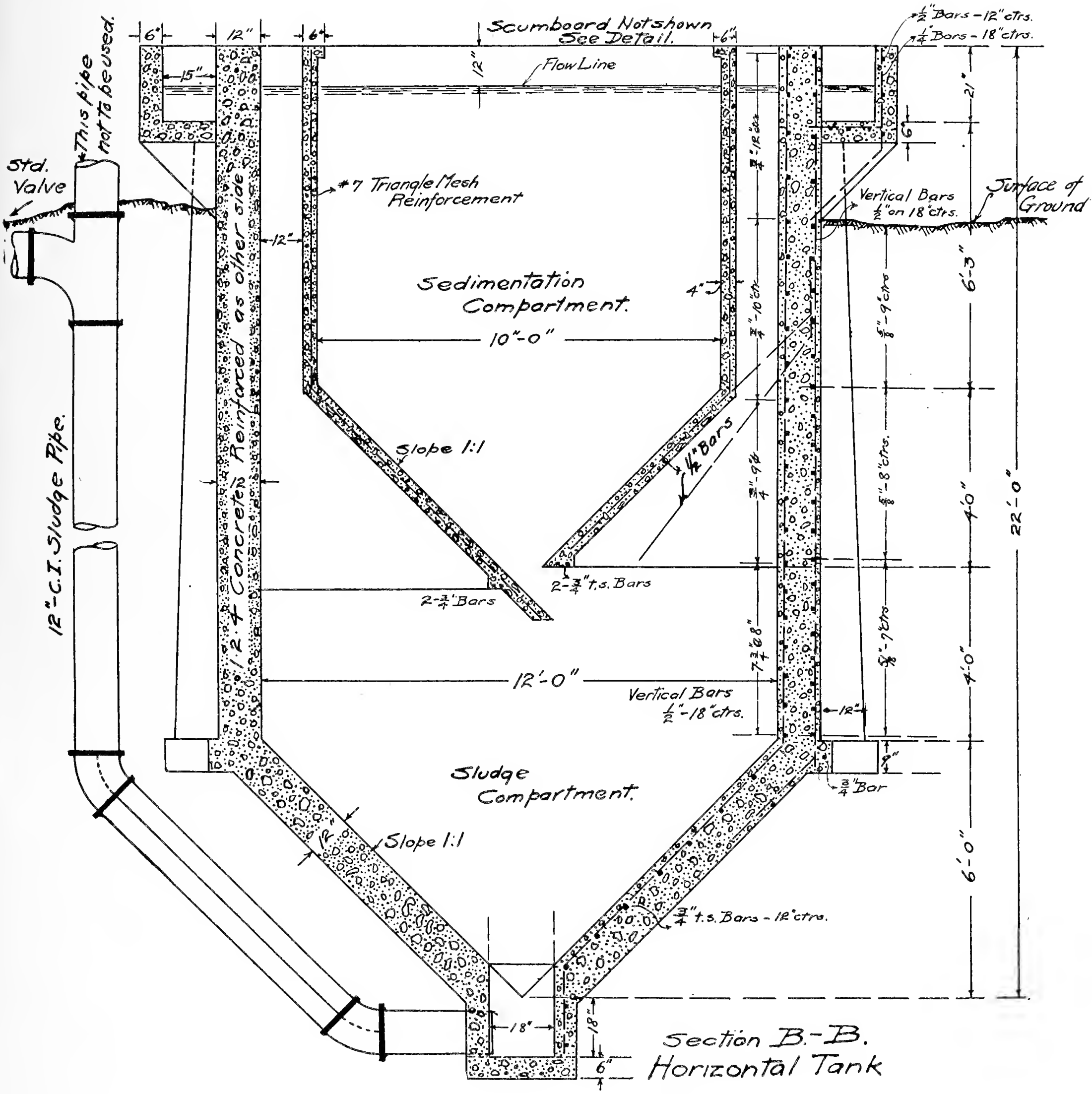
Three-quarter inch twisted bar spaced 10 inches and 12 inches will be used for horizontal reinforcement, while vertical reinforcement will be $\frac{1}{2}$ inch rods spaced 18 inches centers.

Rectangular tank—description. The rectangular tank, as designed, has a tank, 22 feet by 12 feet internal dimensions, and a depth of 22 feet to the bottom of the digestion chamber. The walls are straight and vertical throughout their height, reinforced inside and outside as calculated above for earth pressure and for water pressure. The sedimentation chamber is separated from the digestion or sludge chamber by dividing walls 4 inches thick of concrete, reinforced by triangle [M] mesh or similar metal reinforcement. The sides are supported in the middle of their length by buttresses calculated as cantilevers, while the dividing wall is supported at the ends by the end walls of the tank and in the middle by a wall extending to the level of the slot and reinforced by rods to the main wall.

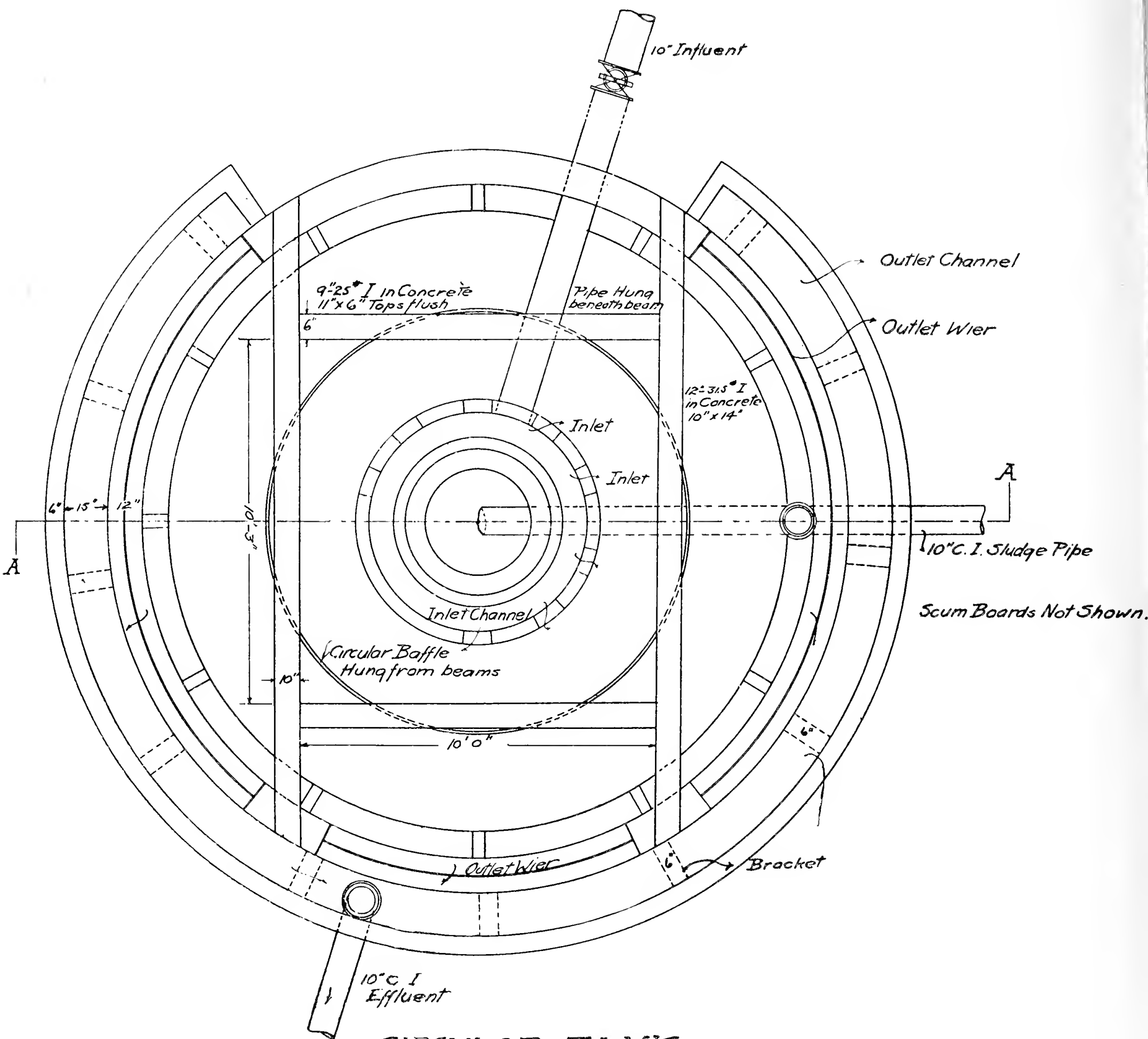
The tank is so arranged that the sewage flow may be reversed in direction through the sedimentation chamber. This is accomplished by a concrete channel 15 inches wide supported on brackets and an arrangement of stop planks of 2 inch boards properly arranged. Sludge is removed from the bottom of the tank by means of a 12 inch cast iron pipe.



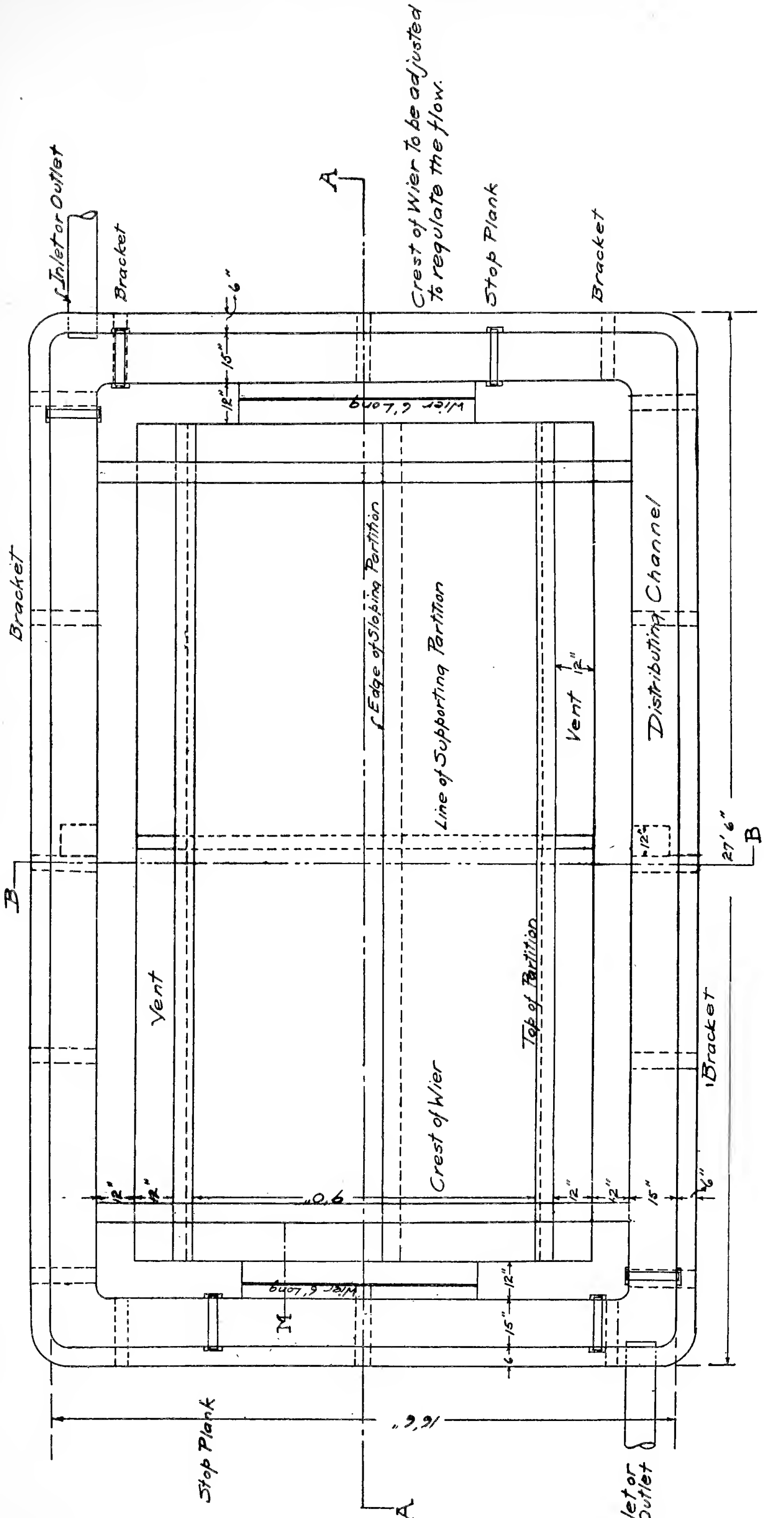
Section A-A
Scale: 1/2"=1'
Horizontal Tank



Section B.-B.
Horizontal Tank



CIRCULAR TANK
PLAN
Scale :- 1/2" - 1'



PLAN OF HORIZONTAL TANK
Scale: $\frac{1}{2}$" = 1'

Sewage enters the sedimentation chamber from the channel over a weir, which is of wood or steel, and can be adjusted in length to produce satisfactory velocities in the tank. Scum-boards are provided at points of inflow and outflow, which may be dispensed with if the sewage is screened previously to its admittance in the tank.

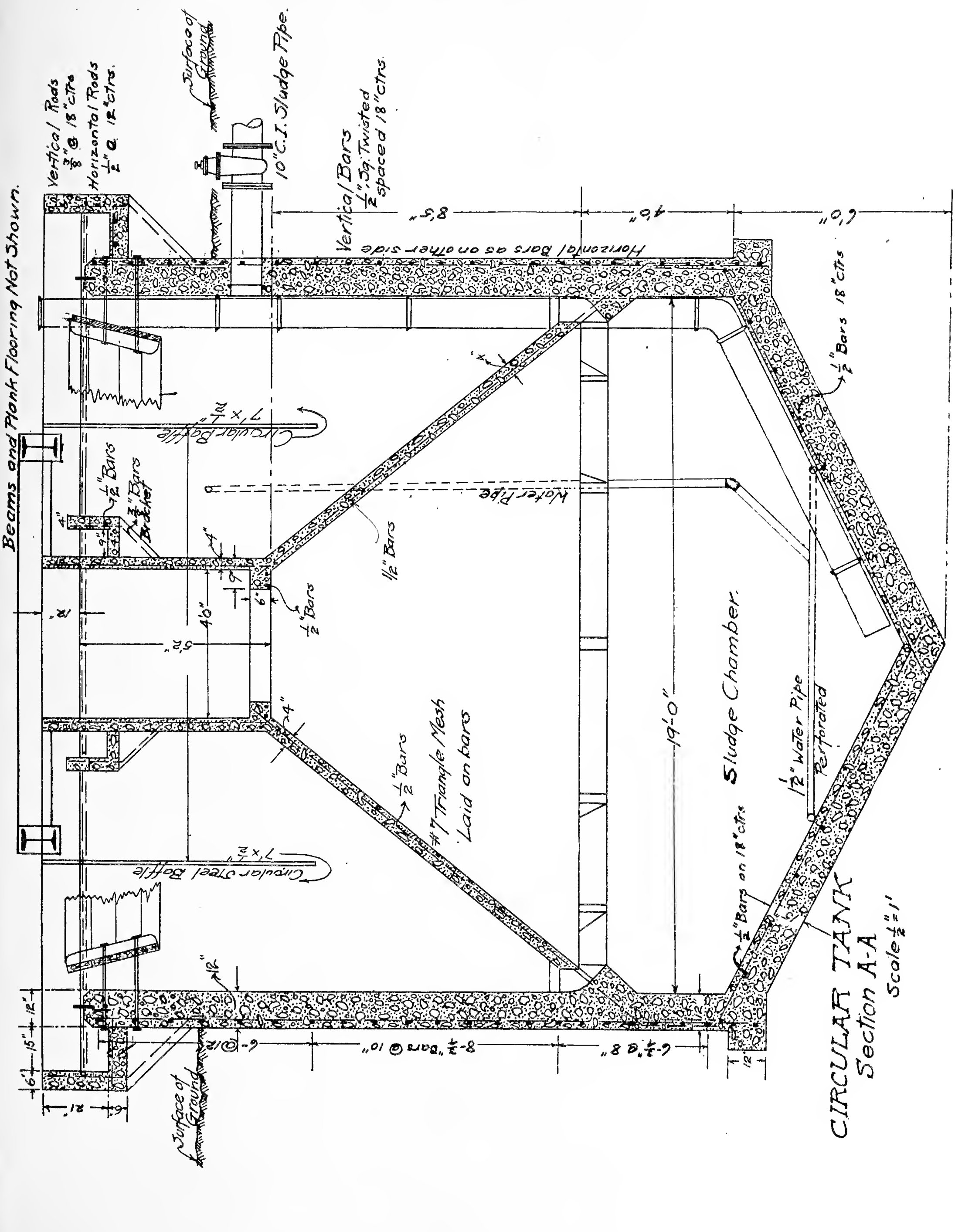
Concrete for the tank shall be in the proportion of 1 : 2 : 4, with either gravel or broken stone of graded sizes. Reinforcement steel is of best quality and must satisfy the specifications of the American Society of Civil Engineers, as found in their last report. Two lines of perforated pipe are placed in the bottom of the digestion chamber, to aid in stirring up the sludge and facilitating its discharge through the discharge pipe.

Circular tank—description. The circular tank is 19 feet in internal diameter, and has a depth below the water line of 22 feet 6 inches. The bottom is conical shaped, the concrete being 15 inches thick and reinforced by radiating bars with circular rods at 18 inch intervals. The dividing walls between the upper and lower compartments is of reinforced concrete, supported by 4 inch brackets to the main wall of the tank at regular intervals. The upper part of conical partition terminates in a circular vent, which supports the distributing channel. Inflowing sewage is conducted by a cast iron pipe to this circular trough or channel, from which it flows through openings of adjustable size into the sedimentation chamber, down under a baffle and out to the outer wall of the tank, portions of which are constructed as weirs and allow the discharge of the clarified sewage into a circular trough on the outside wall, from which it is led to the drainage or filter beds.

Sludge is removed by a 12 inch cast iron pipe lying along the bottom and up one side to an elevation far enough below the water level to furnish proper hydrostatic head.

Baffling is secured by means of a circular baffle, constructed of steel and hung from beams across the top of the tank. These beams are standard I beams encased in a concrete coating to prevent corrosion and add homogeneity to the appearance.

Reinforcement is placed in the outside of the walls and on the conical bottom, and concrete and reinforcement are subject to the same specifications as in the rectangular tank.


Beams and Plank Flooring Not Shown.
Vertical Rods 3/8" @ 18" ctrs
Horizontal Rods 1/2" @ 12" ctrs.
Surface of Ground
10" C.I. Sludge Pipe.
Vertical Bars 1/2" Sq. Twisted spaced 18" ctrs.
Horizontal Bars as on other side
Circular Baffle
Water Pipe
1/2" Bars
#7 Triangle Mesh Laid on bars
Circular Steel Baffle
Sludge Chamber.
1 1/2" Water Pipe Perforated
19'-0"
1/2" Bars on 18" ctrs
1/2" Bars 18" ctrs
CIRCULAR TANK
Section A-A
Scale 1/2"=1'

Comparisons and Conclusions

The comparison of the two tanks will be made on the basis of their cost, clarification efficiency and general qualifications.

COST

In discussing the estimated cost of the tanks, two methods will suggest themselves. One way would be to assume the same unit costs for all items under both tanks and this would resolve itself in a question of comparative quantities, plus whatever extra appurtenances were to be found in either tank.

Several objections can be maintained against this method. First, there will undoubtedly be a difference in the cost of forms, in the circular tank requiring more lumber waste, more carpenter work and more difficult construction. Secondly, the bending and placing of reinforcement takes more time and labor and is more expensive to hold in place. Again, the placing of concrete may be found to be more difficult in the circular forms.

The method of estimating costs that will be followed herein is as follows:

A detailed list of every operation necessary to the construction of each tank will be made, the quantities of each and unit costs for same. The products of quantities and costs, together with whatever operations are scheduled as lump sums, will be equal to the total cost of the tanks.

It may be stated here that cost data that will effectually distinguish between circular and rectangular construction is extremely unreliable and variable. Differences in prices of materials and labor, faulty or insufficient accounting systems, location with respect to supplies and management prevent any adequate or convincing figures.

In the present estimates, only those items which would be liable of any variance will be affected by different prices.

The following items to be found in the construction of both tanks may be said to have probable differences:

Sheeting. This, if necessary for good work in concreting, might seem to be different, but if ordinary sheet piling be used or sheeting supported and braced by waling pieces, the difference in cost would be negligible, for the possible added cost of erection in the circular tank would be offset by the smaller quantity required.

Placing reinforcement in floor. The conical bottom would require much more careful placing, more cutting, and this difference will be taken care of by estimating the cost as 5 cents a pound for the rectangular tank and 6 cents for the circular.

Concreting floors. There will probably be little difference here, as there will be no forms in either tank and small difference in finishing.

Forms for walls. Owing to the extreme variability in cost of lumber, the dearth of adequate or satisfactory cost data, this item will not be considered separately but will be included in the cost of concrete in the two instances as noted below.

Reinforcement for walls. Variations in prices for this will be taken care of in the same proportion as in placing reinforcement for the floor; that is, 5 cents a pound for the rectangular walls and 6 cents a pound for circular.

Concrete for walls. After investigation of cost data covering all available sources, it seems within the limit of accuracy to assume a difference in price for the concrete in circular walls over that in the rectangular walls and to include in that difference all items involved that would be affected. The items involved are erecting forms, placing reinforcement and placing concrete. The price for the rectangular tank will be taken as $12 a cubic yard and that for the circular tank at $14 a cubic yard.

All other items common to both tanks will be assumed at the same unit costs.

QUANTITIES FOR RECTANGULAR TANK

Concrete:	*cubic yards*
Sides	28.5
Ends	16.9
Bottoms	13.2
Buttresses	0.9
Channels	6.2
Partition	9.3
	75.0

Timber:	*feet*
57 feet — 2 x 6 inch cypress plank	57
12 feet — 2 x 4 inch cypress plank	8
28 feet — 6 x 8 white oak plank	112
32 feet — 2 x 6 inch cypress plank	32

Excavation:
400 cubic yards

Piping:
22 feet—12 inch cast iron pipe
65 feet—1½ inch perforated water pipe
1—12 inch cast iron valve
2—12 inch 45 degree turns
1—12 inch 90 degree tee
2—6 feet x ½ inch x 4 inch steel plates

Bolts and nuts:
9—6 inch x ⅜ inch bolts and nuts
24—4 feet x ½ inch bolts and nuts
6—wrought iron strap bolts with nuts

REINFORCEMENT FOR RECTANGULAR TANK

Partition:
744 square feet No. 7 triangle mesh
98—¾ inch bars @ $1.91 pound, 183.5 pounds

Walls:	*pounds*
775 feet—½ inch bars @ $0.85 pound (vertical outside)...............	659.0
575 feet—½ inch bars @ $0.85 pound (vertical inside)................	488.5
828 feet—¾ inch bars @ $1.91 pound (horizontal inside)..............	1582.0
529 feet—⅝ inch bars @ $1.33 pound (horizontal outside)............	704.0

End walls:	*pounds*
(vertical) 16 x 20 = 320 feet — ¾ inch bars @ $1.91 pound............	612.0
(horizontal) 21 x 12.5 feet = 262.5 feet — ¾ inch bars @ $1.91 pound.	502.0
23 x 13.5 feet = 310.5 feet — ⅝ inch bars @ $1.33 pound..............	412.5

Brackets:	*pounds*
6 x 89 feet = 544 feet—½ inch bars @ $0.85 pound....................	462.0
60 x 5 feet = 300 feet—⅜ inch bars @ $0.478 pound..................	143.5

Walls supporting partition:	*pounds*
4—10 feet, ½ inch bars @ $0.85 pound,..............................	34.0

QUANTITIES FOR CIRCULAR TANK

Concrete:	*cubic yards*
Side walls..	44.20
Bottoms...	11.61
Brackets for channels...	4.85
Partition...	3.80
Beam covering...	1.00
	65.46

Reinforcement:	*pounds*
24—½ inch bars at 22 feet (vertical—wall) =	448.0
23—¾ inch bars at 70 feet (horizontal—wall) =	3085.0

5—$\frac{1}{2}$ inch bars at 80 feet (horizontal—brackets) =	340.0
12—$\frac{1}{2}$ inch bars at 20 feet (partition) =	204.0
12—$\frac{3}{8}$ inch bars at 6 feet (vertical—brackets) =	34.5
12—$\frac{3}{8}$ inch bars at 4 feet (vertical—brackets) =	23.0
5—$\frac{1}{2}$ inch bars at 40, 50, 60, 65, 70 feet (bottom—circular) =	242.5
6—$\frac{1}{2}$ inch bars at 4 feet (inlet channel) =	20.2
2—$\frac{1}{2}$ inch bars at 4 feet (inlet channel) =	6.8
12—$\frac{1}{2}$ inch bars at 12 feet (bottom radial) =	122.5
6—$\frac{1}{2}$ inch bars at 6 feet (bottom radial) =	30.6
Total	4567.1

Excavation:
350 cubic yards

Steel:
2—9 inch—25 pound I-beams at $10\frac{1}{4}$ feet long
2—12 inch—31.5 pound I-beams at $17\frac{1}{2}$ feet long
200 square feet triangle mesh
3 Plates—6 x $\frac{1}{2}$ inch—total length = 35 feet weir plates
1 Plate 37 x 7 feet x $\frac{1}{2}$ inch

Pipes and fittings:
23 feet—10 inch cast iron water pipe
1—45 degree—12 inch turn
1—90 degree—12 inch turn
1—12 inch standard valve
6—ring pipe supports
60 feet—$1\frac{1}{2}$ inch water pipe—32 feet long perforated $\frac{1}{8}$ inch holes spaced 4 feet

ESTIMATE OF COST FOR RECTANGULAR TANK

Excavation:	
400 cubic yards at $0.45	$180.00
Sheeting:	
100 linear feet at $1.75	175.00
Placing cast iron sludge pipe:	
22 feet—12 inch pipe at $2.00	44.00
Setting valve	5.00
Back filling and tamping sludge pipe trench	1.50
Placing reinforcement in floors:	
1000 pounds at 5 cents	50.00
Concreting floors:	
13.2 cubic yards at $12.00	158.00
Waterproofing:	
$6\frac{1}{2}$ squares at $3.50	22.70
Reinforcement for Walls:	
5542 pounds at 5 cents	275.00
Concrete for walls:	
46.3 cubic yards at $12.00	550.00

Reinforcement for partition:	
744 square feet No. 7 triangle mesh at $2.50 a square 217.5 pounds bars at 7 cents	18.00
Concrete in partition:	
9.3 cubic yards at $20.00	185.00
Steel weir plates	3.40
Water pipe placed:	
65 feet—1½ inch pipe perforated and fitted with connections. Lump sum	50.00
Reinforcement for brackets and channels:	
605.5 pounds at 7 cents	42.40
Concrete for brackets and channels:	
6.2 cubic yards at $16.00	100.00
Materials for scumboards and supports	15.00
Making and hanging same	10.00
Making stop planks	20.00
Backfilling and embankments	25.00
Placing influent pipe and connections	15.00
Total estimated cost	$2126.40

ESTIMATE OF COST FOR CIRCULAR TANK

Excavation:	
350 cubic yards at $0.45	$157.50
Sheeting:	
80 linear feet at $1.75	140.00
Reinforcement in floors:	
400 pounds at 6 cents	25.00
Concreting floors:	
11.6 cubic yards at $10.00	116.00
Waterproofing:	
3.7 squares at $3.50	15.00
Reinforcement for walls:	
3533 pounds at 6 cents	215.00
Concrete for walls:	
44.2 cubic yards at $14.00	620.00
Placing sludge pipe:	
23 feet—12 inch at $1.50	35.00
Placing sludge pipe valve	40.00
Specials	10.50
Reinforcement for partition:	
300 square feet triangle mesh at $3.00	10.00
231 pounds at 7 cents	18.00
Concrete for partition:	
3.8 cubic yards at $20.00	75.00
Circular steel baffle:	
5400 pounds at 4 cents	210.00

Placing steel beams:	
1600 pounds at 4 cents	65.00
Water pipe placed:	
60 feet—$1\frac{1}{2}$ inch pipe—perforated and fitted	50.00
Reinforcement for brackets and channels:	
400 pounds at 7 cents	28.00
Concrete in brackets:	
4.85 cubic yards at $16.00	75.00
Concrete in top beams	20.00
Weir plates	10.00
Placing influent pipe and connections	15.00
Total estimated cost	$1950.00

In the estimate of cost, certain variations in cost items, not hitherto mentioned, are to be found.

The sludge pipe can be placed in the inside of the finished tank more cheaply than in the earth outside, hence the prices of $1.50 and $2 respectively.

Reinforcement in floors is given at 5 and 6 cents a pound, as previously noted.

Concreting floors is given at $10 in both tanks.

Reinforcement for walls is given at 5 and 6 cents as noted, and for reasons already given.

Concrete for walls is given at $12 and $14.

Triangle mesh in place is assumed at $2.50 and $3 and the lump sums are not those obtained by strict multiplication.

Concrete in the partitions is given at $20 and in the outside brackets at $16. While these are only estimates, it would seem that they are close enough to the proper value.

A cheaper type of baffle and top construction for the circular tank would materially increase the financial advantage of the circular tank. The resulting estimates from the above considerations do not allow much advantage to either side, and peculiar conditions might even throw this advantage entirely on the other side.

However, it would seem that while the units cost has been figured as greater for the circular tank, the often stated advantage of that latter type over the former may be seen to be based on a small margin of difference.

CLARIFICATION EFFICIENCY

As regards clarification efficiency, certainly the advantage will lie in the circular tank. While the advantage of the deep baffle may not be great, certainly the period of low velocity will be of value in securing efficient sedimentation. The uniform flow in radial lines will remove the necessity for ever reversing flow and will stabilize the flow in such manner as to permit the most normal conditions of settling.

In consideration of the many probable items of difference and chance involved in either estimate, when applied to a single installation, it would be the writer's conclusion and thesis that the advantages of the circular radial-flow type of Imhoff tank over the type known as rectangular-linear flow must lie mainly upon its advantages as to clarification efficiency. And here too, enough questions will arise to make the problem one that can be best solved for each location or installation.

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GEOGRAPHIC FACTORS IN THE ESTABLISHING OF THE OHIO-MICHIGAN BOUNDARY LINE[1]

Constance G. Eirich

Herder tells us that history is geography set into motion; Miss Semple says: "Today a fact of geography becomes tomorrow a factor of history." Several facts of geography are fundamental in the dispute between Ohio and Michigan over the boundary question. In origin, this long and bitter quarrel resembled the state and colonial contentions over boundaries, all of which arose from either ignorance of local geography, or an unpardonable disregard of vested rights. Michigan claimed her boundary as a vested right from the ordinance of 1787;[2] whereas Ohio urged that the ordinance based its determination on erroneous geographical facts; hence the boundaries as laid down in it should not be strictly binding.

The geographic factors involved in the question are: (1) the true location of the Southern end of Lake Michigan; (2) the physiography, coast line and harbors of the western part of the Erie basin; (3) the prospective canals of Ohio; (4) population, i.e., relative size of the two groups concerned.

Southern End of Lake Michigan

In the ordinance of 1787, Congress reserved the right to form one or two states in that part of the North West Territory which lay north of an east-west line drawn through the southern bend or extreme of Lake Michigan. This line would form the southern boundary between the states to be created later. The trouble arose from the fact that due care was not exercised in determining the line. Maps of the Western country extant at the time of the ordinance was adopted show the south end of Lake Michigan to be so far north of its true position that the northern boundary of the

[1] This paper was prepared in connection with a course in geography at the University of Michigan, under the direction of Prof. Frank Carney. Reprinted from *Journal of Geography*, vol. xii, pp. 5–8, September, 1913.

[2] Tuttle, Charles R., *General History of Michigan*, 1873, p. 450.

territory of Ohio was laid down at nearly the 42nd parallel, being indicated on the map by a pencil line drawn from the southern bend of the lake to the Canadian line, intersecting Lake Erie between the River Raisin and the town of Detroit. No further thought was given this indefinite boundary until Ohio moved to become a state. Ohio's constitutional convention, which convened at Chillicothe in 1802, was proceeding on the assumption that the old maps were correct, and the line as defined in the ordinance would terminate at some point north of Maumee Bay. While the subject was under discussion, a man, formerly a hunter in the Lake Michigan country, mentioned the fact that the lake extended much farther south than was generally supposed. This possibility immediately alarmed the members of the convention, who, in order to provide against the contingency that the line mentioned in the ordinance, might be further south than was commonly supposed, inserted in their constitution the famous "proviso" to the effect, that if the southern bend of Lake Michigan should extend so far south that a line drawn due east from it should not intercept Lake Erie, or if it should intersect the lake east of the mouth of the Maumee River, then with the assent of Congress, the northern boundary should be established by, and extend to, a line running from the southern end of Lake Michigan to the most northerly extreme of Maumee Bay.[3] Ohio's constitution was accepted by Congress, though no special mention was given to the "proviso." Owing to the fact, however, that the constitution was accepted by Congress, many Ohio people took it for granted that Congress had recognized the "proviso," and that the line was thus legally fixed. The boundary dispute therefore had its genesis in an incorrect map.

Area in Dispute

Population in this area was so sparse that the boundary line question was dormant till the expanding industries of the more thickly settled parts of Ohio demanded transportation outlets, and the state began to discuss canals. Lake ports, and their hinterlands at once became regions worth serious consideration. Michigan held to the line as literally laid down in the ordinance, since it gave her the harbor of Maumee with a strip of land 5

[3] Cooley, Thomas M., *Michigan*, 1905, pp. 216–217.

miles wide on the west and 8 miles wide on the east. Naturally Ohio urged the boundary of her "proviso" which placed these advantages in her domain. The limits which Michigan proposed would have made her a larger state than Ohio and one of the largest in the Union at that time; Ohio would then be one of the smallest of the western states. Furthermore, Michigan would have a longer coast line than any other state of its size; Ohio, being on one of the smallest of the Great Lakes, would have very little coast line. Hence it seemed equitable to give Ohio all the coast line that was possible even at the expense of Michigan. If Michigan did lose Maumee Bay she still had a good harbor on Lake Erie. At that time, Ohio was considered the key to the west because of her location between the new and the old country, and her accessibility to old centers of settlement, hence the commercial interests of Ohio, as well as of the country at large, demanded that Ohio should have as many lake ports as possible.

Prospective Canals

Associated with the Maumee harbor is perhaps the most important factor in the boundary dispute—the influence of the canals. The Erie Canal, completed in 1825, stimulated the western states to open up their interiors by canals, that they might profit through this waterway to the east. The stimulus was first felt by Ohio because of its nearness to the western terminus of the Erie Canal. The long lake frontier on the north, the narrow width between Lake Erie and the navigable Ohio on the south and east, and the interior rivers, suggested the feasibility and advantages of an extensive system of artificial waterways. At this time, too, steamboats were operating on the lakes and rivers, greatly enhancing the value of Maumee Bay as well as developing the full usefullness of the interior water ways, both as avenues of immigration and means of trade.

The next influence bearing on the boundary question was the Miami-Erie Canal which was to connect the Ohio River at Cincinnati with Lake Erie. This canal was contemplated about 1825 and begun in 1830 though not completed until 1845, almost eight years after the boundary was fixed, that is, in 1837, the year Michigan was admitted as a state. It was the anticipated advantages of the canal which affected the boundary question. The

Wabash-Erie Canal was surveyed in 1836 and completed about 1845; but the agitation which resulted in this canal was an important factor in the boundary dispute. The canal propaganda was supported by Ohio capitalists and by those interested in Ohio, but living in the east, a group of whom had undertaken to build a city at Toledo, and others had interests in other towns of the disputed territory. These men were actively interested in Ohio's contention over the boundary; they foresaw that canals would be a means of opening up a large central area of farms which formed an isolated district practically cut off from the Ohio River and the lake, and would thereby increase the growth and prosperity of the state.

The Miami-Erie Canal was considered a good transportation route for manufacturers from the eastern cities to the great river valley at, and below Cincinnati. The Wabash-Erie Canal was expected to control Indiana trade. Toledo, aided by these canals and its position on the lake, was predicted to be one of the greatest gathering points of agricultural productions in the country; and was considered equally favorable for the distribution, over the lakes, of southern products, sugar and tobacco. At that time canals were the most important means of transportation. Their construction required large expenditures, and too great risk as to profits for individuals or companies to undertake, hence the canals were to be owned by the state. Ohio, having a relatively dense population, and considerable wealth, was able to undertake constructing canals; her accessibility to the older centers of settlement was a factor in the prevalent optimism. Ohio capitalists recognized the natural advantages of Toledo as the northern terminus of a canal; other termini were considered, but Toledo was found to be the only practicable one from an engineering point of view. The industrial purposes of a canal in western Ohio would be but partly fulfilled if some other harbor had to be used. Ohioans therefore insisted upon the "proviso" of their constitution.

Thus when Michigan began to make known her claims to the boundary as specified in the ordinance, canal building came to a sudden halt. Toledo was the physiographic terminus; the thought of Ohio constructing so expensive a channel of trade and then turning its traffic into a Michigan port was not to be entertained. Michigan was anxious to avail herself of whatever ad-

vantage she might receive from her neighbors' necessity. The boundary question did not assume its really great importance until the northern terminus of the Miami-Erie Canal came up for final decision. The inhabitants of the disputed district had acquiesced in being ruled by the Michigan Territory; however, the boundary line discussion soon led them to take the side of Ohio; the population immediately concerned in the disputed area did not support Michigan.

Population as a Factor

Northern Ohio did not have a large population in 1830; in the Ohio part of the Maumee drainage basin there were about 11,000. The contiguous part of Michigan contained about 15,500. So far as the ratio of local population is concerned the advantage was with Michigan. In 1840 the population of these same regions of Ohio and Michigan was 56,680 and 75,555 respectively. From these statistics alone we would expect Michigan to have had the greatest influence, though we know such was not the case.

The question in dispute was of interest to the entire population of each political division; consequently in this particular the strength of the two political divisions was measured by their relative populations. In 1830 the population of Ohio was 937,903, of Michigan, 31,639; in 1840 Ohio numbered 1,519,467, while Michigan had only 212,267. Capitalists of Ohio, as well as eastern capitalists who were interested in Ohio, had faith in numbers, and accordingly exerted all the political influence possible. Michigan did not have a corresponding population-momentum, a vital geographic influence, though only a corollary of more basal geographic factors. A Michigan delegate to Congress, Mr. A. E. Wing, declared[4] that a Cincinnati company, interested in the canal, and bodies of eastern capitalists, sent lobbies to Washington to induce Congress to extend the domain of Ohio to the northern boundary. Furthermore, Ohio's population was an influential political body whose good will was essential to the President in the coming election, though this fact as a basis for the President's action in the case may have operated only subconsciously.

[4] Soule, A. M., *Southern and Western Boundary of Michigan.* Mich. Pol. Sc. Ass., vol. ii, no. 2, May, 1896, p. 51.

Conclusion

These four factors: the position of the southern end of Lake Michigan; the physiography of the Maumee basin and its harbors; the prospective canals; and the momentum of the populations involved, were very important in establishing the boundary line. There were years of Congressional disputes; and politics in its good and bad phases became a feature, but these were only manifestations of the fundamental geographic influences.

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A METHOD OF SUBDIVIDING THE INTERIOR OF A SIMPLY CLOSED RECTIFIABLE CURVE WITH AN APPLICATION TO CAUCHY'S THEOREM

F. B. Wiley and G. A. Bliss

The Jordan[1] proof of the Cauchy theorem requires that all points of the closed curve C and its interior lie in a region in which the integrand function is continuous and has a continuous derivative. In the Goursat and in the Moore proofs[2] the requirement that the derivative be continuous is avoided, but there are still restrictions on the character of the curve C other than that it be rectifiable. These restrictions are indicated in Moore's statement of the theorem which we quote:

"The definite integral

$$\int_C f(z)\, dz$$

exists and has the value zero, if

(1) the path of the integration C is a simply closed continuous rectifiable curve met by the various lines parallel to the xy-axes in the z-plane ($z = x + iy$) in a finite number of points and segments of coincidence, and moreover having the property (2);

(2) for every point ζ of C, if a square with sides parallel to the axes converges in any way to the point ζ, the ratio of the total length of the arcs of C lying on the square to the perimeter of the square is ultimately less than a certain constant ρ_ζ which may vary as ζ traverses C;

(3) on the region R, consisting of the curve C and its interior region, the integrand function $f(z)$ is a single valued continuous function of z with a single valued derivative $f'(z)$."

The restrictions of (1) and (2) on the path of integration C, otherwise than that it be closed and rectifiable, have been avoided by Moore at the close of the article to which we have referred, by

[1] Jordan, *Cours d'Analyse*, 2d. ed., vol. 1, (1893), §§196–198.

[2] Goursat, *Cours d'Analyse Mathématique*, vol. 2, (1911), §§286–7. Moore, *Transactions of the American Mathematical Society*, vol. 1, (1900) p. 499.

applying his method of proof to the triangle to which Jordan[3] reduces the problem.

Our purpose in this paper is to accomplish the same result for a simply closed curve by applying a subdivision theorem due to Bliss[4] which takes the place of the Jordon reduction to a triangle.

We start with a simply closed rectifiable curve C which is entirely interior to a region in which the integrand function $f(z)$ is continuous and has at each point a unique derivative. Our method consists in showing in the first place, in §1, that the region enclosed by the curve can always be subdivided into a finite number of regions[4] each of which can be surrounded by a rectangle in which $f(z)$ satisfies the above hypothesis. Then in §2 it is shown that Cauchy's theorem holds for each of these rectangles and consequently (§3) the Cauchy theorem holds for any simply closed rectifiable curve in each rectangle. It readily follows that (§4) the Cauchy theorem holds for our original curve C.

§1. A Method of Subdividing the Interior of a Simply Closed Rectifiable Curve

In this section we show, after stating certain preliminary theorems, first, by means of an auxilliary theorem and then a main theorem, how the interior of a simply closed rectifiable curve C may be subdivided into regions each of which has its maximum diameter less than an arbitrarily assigned constant ϵ; and second, for a curve C lying in a simply connected continuum, that the number of subdivisions necessary to permit each subregion to be surrounded by a rectangle lying wholly in the continuum is finite—a formula for the maximum number being exhibited. It is understood that by a rectifiable curve is meant a continuous curve with length.

We are presupposing the following theorems.[5] Any simply closed rectifiable curve C in an xy-plane divides the plane into two continua, an exterior and a finite interior. Any two interior

[3] *Loc. cit.*

[4] Bliss, *Princeton Colloquium*, Part I, p. 29.

[5] Osgood, *Lehrbuch der Funktionen Theorie*, chapt. V.; Bliss, A Proof of the Fundamental Theorem of Analysis Situs, *Bulletin of the American Mathematical Society*, Vol. 12 (1905–06), p. 336; also Brouwer, Beweis des Jordanschen Kurvensatzes, *Mathematische Annalen*, vol. 69 (1910), p. 169.

points can be joined by a rectifiable curve every point of which is an interior point, and a similar statement holds for exterior points. Any continuous curve joining an interior point and an exterior point must have on it at least one point of the curve C. Every point of C is a limit point of both interior and exterior points.

We define, for the moment, the effective length of a curve to be the length of that part of the curve that lies in no horizontal line.

We state the auxiliary theorem;

If y_1 and y_2 are the maximum and minimum values of y in the interval

$$t' \leqq t \leqq t''$$

for a simply closed rectifiable curve C

$$x = \varphi(t), \qquad y = \psi(t) \qquad\qquad (t' \leqq t \leqq t'')$$

then there is a segment $p'p''$ of the horizontal line l,

$$y = \tfrac{1}{2}(y_1 + y_2),$$

interior to C except for its end points, which forms with C two simply closed rectifiable curves. If

$$y_1 - y_2 > \epsilon,$$

the segment can be so introduced that each of these curves has an effective length greater than ϵ.

Let p_1 and p_2 be the two points on C at which y is a maximum and a minimum respectively. Select points p'_1 and p'_2 which are interior points of C and so near to p_1 and p_2, respectively, that the former is above the line l and the latter below it. We may join the points p'_1 p'_2 by means of a continuous polygen D having a finite number of sides and consisting entirely of interior points of C.

Any side of D which has an end point in common with the line l may be rotated slightly about its other end point, and in this way it may be brought about that D has only interior points of its sides in the line l, and actually crosses the line where they have a point in common.

The polygon D must intersect l at least once, say at a point p, since one end point of D is above and the other is below the line. There will be a segment $p'p''$ of l containing p such that p' and p'' are on the curve C while every other point of the segment is interior to C. There can be only a finite number of such segments $p'p''$ since D has at most a finite number of intersections with the horizontal line. There must be at least one of them on

which D has an odd number of intersection points, since otherwise both end points of D would be on the same side of the line l.

If $p'p''$ is such a segment, then it forms with C two simply closed rectifiable curves C_1 and C_2 one of which encloses p'_1 and the other p'_2, for after its last intersection with $p'p''$ the polygon D, and hence p'_2, is entirely exterior to the curve C_1.

If $y_1 - y_2$ is greater than ϵ, then the point p'_1 can be chosen so near to p_1 that its vertical distance to the line l is greater than $\epsilon/2$. The altitude of the curve C_1 must then be greater than $\epsilon/2$. The effective length must at least equal twice the altitude. Thus the effective length of C_1 is greater than ϵ. C_2 is handled in like manner.

We now take up the main theorem of this section:

The interior of a simply closed rectifiable curve.

$$x = \varphi(t), \qquad y = \psi(t) \qquad (t' \leqq t \leqq t'')$$

can be divided by a finite number of segments of straight lines into regions each of which has a maximum diameter less than an arbitrarily assigned positive constant ϵ.

If the altitude of any closed curve is greater than ϵ, the effective length of either of its two parts after subdivision by a horizontal line segment, as described in the auxiliary theorem, will be less than $L - \epsilon$ where L is the length of the curve.

If the altitude $y_1 - y_2$ of C is greater than ϵ, then the effective arc of either C_1 or C_2 will be greater in length than ϵ and the effective arc of each will also be less than $L - \epsilon$, where L is the perimeter of C as above.

The curves C_1, C_2 may next be subdivided as in the auxiliary theorem. If the curve C_1 for example, has still an altitude greater than ϵ, the two curves into which it is subdivided will have effective lengths less than $L - 2\epsilon$. By a continuation of this process of simultaneous subdivision the interior of C will be subdivided after n steps into regions bounded by simply closed rectifiable curves whose altitudes are $< \epsilon$ or else whose effective lengths are less than $L - n\epsilon$. If $n \geqq L/\epsilon - 2$ then each subdivision will be in altitude, or else have effective length, $< 2\epsilon$. But in the latter case also its altitude must be less than ϵ.

In a similar manner the regions so formed may be subdivided by vertical segments into others whose breadths are less than ϵ.

If in the above discussion we replace ϵ by $\epsilon/\sqrt{2}$, the theorem follows at once since each sub-region lies in a square of side $\epsilon\sqrt{2}$ and hence has a diameter less than ϵ.

The number of line segments necessary for the subdivision of the region in the interior of C into regions of diameters less than ϵ is not greater than $4^{L\sqrt{2}/\epsilon}$.

To develop this formula we note, by continuing the process indicated in the main theorem, that 2^n-1 line segments give 2^n regions each with altitude less than ϵ or else with an effective arc less than $L-n\epsilon$. By taking n greater than L/ϵ we see that any arc with altitude still greater than ϵ would necessarily have effective length less than zero, which is impossible. This gives $2^{L/\epsilon}$ as a maximum for the number of regions necessary for the subdivision of C into sub-regions with altitudes less than ϵ. In a like manner we show that $2^{L/\epsilon}$ is a maximum for the number of sub-regions into which each of the regions just obtained needs to be divided to insure that the breadth of each will be less than ϵ. It follows that $4^{L/\epsilon}$ is a maximum for the number of sub-regions into which it is necessary to divide the interior of C so that the length and breadth of each region will be less than ϵ, while $4^{L\sqrt{2}/\epsilon}$ is a maximum for the number of sub-regions into which it is necessary to divide the interior of C to insure that the maximum diameter of each region be less than ϵ, and this can be accomplished by drawing not more than $4^{L\sqrt{2}/\epsilon}$ line segments.

The continuation of the subdividing process until the maximum diameter of each region is at most ϵ, where ϵ is taken less than the minimum distance from C to the boundary of a continuum in the interior of which the curve is supposed to lie, insures that each region may be surrounded by a rectangle lying wholly in the continuum and establishes the proof of the corollary we now state.

If our given curve C lies in a simply connected continuum and if ϵ is taken less than the minimum distance from C to the boundary of the continuum, then $4^{L\sqrt{2}/\epsilon}$ is a maximum for the number of line segments necessary to divide the region in the interior of C into sub-regions each of which may be surrounded by a rectangle lying wholly in the continuum.

§2. The Cauchy Theorem for a Rectangle

In the present section we show that the definite integral

$$\int_R f(z)\,dz$$

exists and has the value zero, where R is the border of a rectangle in the interior of, and on which, $f(z)$ is holomorphic.

We take up at once the theorem of this section of the paper, using the method of proof due to Moore.[6]

The definite integral

$$J = \int_R f(z)\,dz$$

exists and has the value zero if the path of integration R is any rectangle, and if in the interior of R and on R itself the integrand function $f(z)$ is a single valued continuous function of z with a single valued derivative $f'(z)$.

We may consider without loss of generality the rectangle R as given with its sides parallel to the xy–axes. Since the path curve R is rectifiable and $f(z)$ is continuous on R the integral J exists.[7] We show by indirect proof that $J = 0$.

Set $|J| = \eta$ and assume $\eta > 0$. By the introduction of two diameters, the rectangle is subdivided into four equal rectangles

$$R_1', R_1'', R_1''', R_1''''.$$

Define J_1' and η' by the equalities

$$J_1' = \int_{R_1'} f(z)\,dz, \qquad |J_1'| = \eta_1',$$

and likewise for J_1'', J_1''', and J_1''''. Then we have

$$J = J_1' + J_1'' + J_1''' + J_1''''$$

and

$$0 < \eta \leqq \eta_1' + \eta_1'' + \eta_1''' + \eta_1''''.$$

Hence at least one of the four η_1's must be at least $\eta/4$. Choose such an η_1 and denote it by η_1 without superscript. Do likewise

[6] *Loc. cit.*

[7] Moore, *loc. cit.*

for the corresponding J_1 and R_1. Then in R_1 we have $\eta_1 > 0$ as in the original rectangle R we had $\eta > 0$.

Thus for every integer ν there is a rectangle R_ν whose longest side is $\gamma/2^\nu$ when γ is the largest side of R. The integral

$$J_\nu = \int_{R_\nu} f(z)\, dz$$

satisfies the inequality.

[1] $$|J_\nu| = \eta_\nu \geqq \eta/4^\nu.$$

This dissection process determines a definite point $z = \zeta$ which lies in every rectangle R_ν, and is either interior to or on R. For every point z of the rectangle R_ν one has the inequality

$$|z-\zeta| \leqq \sqrt{2}\,\gamma\, 2^{-\nu}.$$

We set for points z interior to or on R

$$f(z) = f(\zeta) + (z-\zeta) f'(\zeta) + \Delta(z).$$

By introducing a positive number ϵ subject to later determination, one has interior to or on R_ν

[2] $$|\Delta(z)| \leqq \epsilon |z-\zeta| \leqq \epsilon\gamma\, 2^{-\nu}\sqrt{2}$$

provided that ν is taken sufficiently large, say greater than ν_ϵ.

We now integrate along the rectangle R_ν. This gives

$$J_\nu = \Big[f(\zeta) - \zeta f'(\zeta)\Big] \int_{R_\nu} dz + f'(\zeta) \int_{R_\nu} z dz + \int_{R_\nu} \Delta(z)\, dz$$

which in turn gives

[3] $$J_\nu = \int_{R_\nu} \Delta(z)\, dz$$

in view of the fact that $\int dz$ and $\int z dz$ taken along R_ν are seen without difficulty to vanish.

From [2] and [3] we obtain

$$|J_\nu| = \eta_\nu \leqq \sqrt{2}\,\epsilon\gamma\, 2^{-\nu} \lambda_\nu,$$

where λ_ν is the total length of the rectangle R_ν. Since

$$\lambda_\nu \leqq 4\gamma\, 2^{-\nu},$$

then

$$\eta_\nu \leqq 4\sqrt{2}\,\epsilon\gamma^2\, 4^{-\nu}.$$

This, because of [1], gives

$$\eta \leqq 4\sqrt{2}\,\epsilon\gamma^2.$$

But the positive number ϵ remains at our disposal and, since η is greater than zero, may now be so chosen that

$$4\sqrt{2}\,\epsilon\gamma^2 < \eta.$$

This is in contradiction with the preceding inequality, and completes the proof of the theorem.

§3. The Cauchy Theorem for Any Simply Closed Rectifiable Curve in a Rectangle in Which the Integrand Function Has a Derivative.

In this section we establish the theorem:
The definite integral

$$\int_C f(z)\, dz$$

exists and has the value zero if the path of integration C is any closed rectifiable curve consisting only of interior points of a rectangular region on which the integrand function $f(z)$ is a single valued continuous function of z with a single valued derivative $f'(z)$.

We establish this theorem by setting up a single valued function $F(z)$ which has the derivative $f(z)$, and then showing by means of an auxiliary theorem that for any rectifiable curve C in the rectangle

$$F_1(Z) - F(z_0) = \int_{z_0 C}^{Z} f(z)\, dz,$$

from which the proof of the main theorem follows.

The integral

$$\int_C f(z)\, dz$$

exists because the curve C is rectifiable and the function $f(z)$ is continuous on C.[8] We define R (Fig. 1) as a rectangle with its sides parallel to the xy-axes; (a, b) as the lower left-hand vertex of R; z as any point (x, y) of the rectangle; L as the path from (a, b) to (x, y) that is parallel to the axis of reals from (a, b) to (x, b) and then parallel to the axis of imaginaries from (x, b) to (x, y); L' as the path that is parallel to the axis of imaginaries from (a, b) to (x, y) and then parallel to the axis of reals from (a, y) to (x, y); and

$$F(z) = \int_L f(z)\, dz.$$

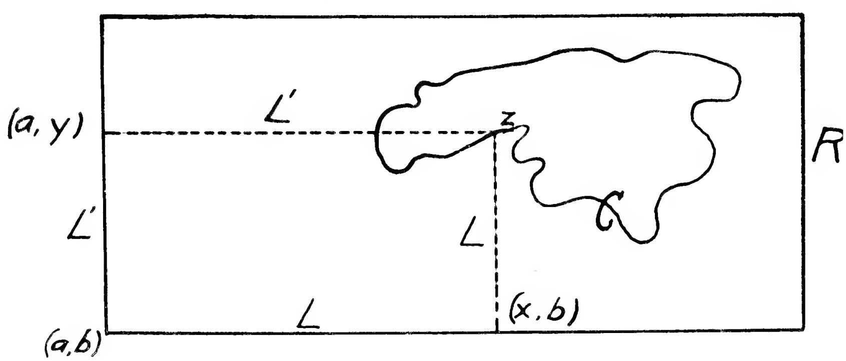


FIG. 1

From the definitions it follows that

[4] $$F(z) = \int_a^x f(x+ib)\, dx + i \int_b^y f(x+iy)\, dy.$$

In consequence of Cauchy's theorem for a rectangle as proved in §2 this may be written

[5] $$F(z) = i \int_b^y f(a+iy)\, dy + \int_a^x f(x+iy)\, dx.$$

From [4] we have

$$\frac{1}{i}\frac{\partial F(z)}{\partial y} = f(x+iy) = f(z)$$

[8] Moore, *loc. cit.*

and from [5]

$$\frac{\partial F(z)}{\partial x} = f(x+iy) = f(z).$$

Thus

$$\frac{\partial F(z)}{\partial y} = i\,\frac{\partial F(z)}{\partial x},$$

from which we see that the Cauchy-Riemann differential equations are satisfied and $F(z)$ is monogenic. We conclude that

There exists a function $F(z)$ well defined and single valued in the rectangle R and such that

$$\frac{dF(z)}{dz} = f(z)$$

for every z in R.

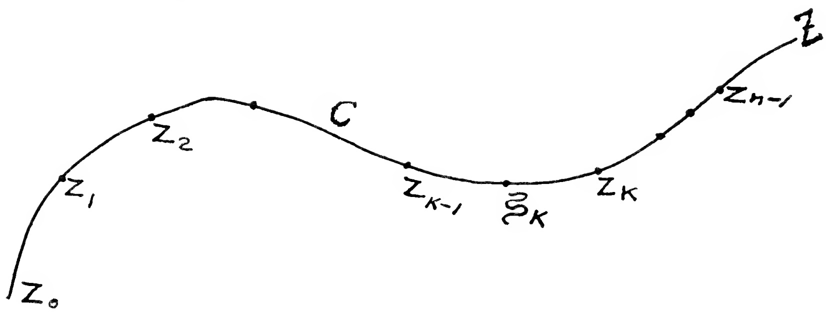


Fig. 2

We next take up a second auxiliary theorem:

If in a neighborhood of a rectifiable curve C the function $f(z)$ is single valued and continuous and the derivative of a single valued continuous function $F(z)$, then

$$\int_{z_0 C}^{Z} f(z)\,dz = F(Z) - F(z_0),$$

where z_0 and Z are the end points of C (Fig. 2).

For use in this theorem we shall understand that

$$\int_{z_0 C}^{Z} f(z)\,dz = \underset{\Delta z=0}{\mathrm{L}} \sum_{k=1}^{n} f(\zeta_k)\,\Delta z_k,$$

where z_k ($k = 1 \ldots\ldots, n$) are ordered points on the arc z_0Z of the curve C, z_n being the same as Z, and ζ_k is any point on the arc $z_{k-1}z_k$, while Δz_k is the chord $z_k - z_{k-1}$.

Let K be a curve

$$x = \varphi(t),\ y = \psi(t) \qquad (t_0 \leqq t \leqq T)$$

for which φ and ψ are not only continuous but except at a finite number of points have continuous derivatives. We now establish our theorem by showing first that along a curve K, for example a polygon, which satisfies these continuity conditions, we have

$$\int_{z_0K}^{Z} f(z)\, dz = F(Z) - F(z_0).$$

We then complete the proof by using Jordan's[9] method of proving that the value of the integral along a polygon K inscribed in the arc C approaches the value of the integral along C, where C is any rectifiable curve, from which we are able to show that

$$\int_{z_0C}^{Z} f(z)\, dz = F(Z) - F(z_0).$$

Taking up the first step in the proof we may write $\zeta = \xi + i\eta$ and for one of the intervals along the curve K we may write

[6] $$f(\zeta_k)\, \Delta z_k = [u(\xi_k, \eta_k) + iv(\xi_k, \eta_k)]\,(\Delta x_k + i\Delta y_k) =$$
$$u(\xi_k, \eta_k)\,\Delta x_k - v(\xi_k, \eta_k)\,\Delta y_k + iv(\xi_k, \eta_k)\,\Delta x_k + iu(\xi_k, \eta_k)\,\Delta y_k.$$

If now we let τ_k be the value of t for which, by the mean value theorem,

$$\Delta x_k = \varphi'(\tau_k)\,\Delta t_k,$$

where Δt_k is the t-interval corresponding to Δx_k, and let (ξ_k, η_k) be the point on K corresponding to τ_k, then we have for the first term of [6]

$$u(\xi_k, \eta_k)\,\Delta x_k = u[\varphi(\tau_k), \psi(\tau_k)]\,\varphi'(\tau_k)\,\Delta t_k.$$

We now sum these expressions for $k = 1$ to n and then pass to the limit as $\Delta\tau$ approaches zero. This gives

$$\mathop{\mathrm{L}}_{\Delta z = 0} \sum_{k=1}^{n} u(\xi_k, \eta_k)\,\Delta x_k = \int_{t_0}^{T} u[\varphi(t), \psi(t)]\,\varphi'(t)\,dt.$$

[9] *Loc. cit.*

After treating the three remaining terms of [6] in the same manner, we have

$$[7] \quad \int_{z_0 K}^{Z} f(z)\, dz = \int_{t_0}^{T} [u\varphi'(t) - v\psi'(t)]\, dt + i \int_{t_0}^{T} [u\psi'(t) + v\varphi'(t)]\, dt,$$

where u and v are functions of $\varphi(t)$ and $\psi(t)$ as expressed above. Furthermore we know that

$$\int_{t_0}^{T} [u\varphi'(t) - v\psi'(t)]\, dt = \Phi(T) - \Phi(t_0)$$

and

$$\int_{0}^{T} [u\psi'(t) + v\varphi'(t)]\, dt = \Psi(T) - \Psi(t_0)$$

provided that $\Phi(t)$ and $\Psi(t)$ are anti-derivates of the functions

$$u\varphi'(t) - v\psi'(t), \qquad u\psi'(t) + v\varphi'(t),$$

respectively. But if we write

$$F(z) = U(x, y) + i V(x, y),$$

we have, according to the proof of the first theorem of this section,

$$\frac{\partial U}{\partial x} = u, \quad \frac{\partial V}{\partial x} = v, \quad \frac{\partial U}{\partial y} = -v, \quad \frac{\partial V}{\partial y} = u,$$

and hence

$$\int_{t_0}^{T} [u\varphi'(t) - v\psi'(t)]\, dt = U(X, Y) - U(x_0, y_0),$$

$$\int_{t_0}^{T} [v\varphi'(t) + u\psi'(t)]\, dt = V(XY) - V(x_0, y_0).$$

From this result and [7] it follows that

$$\int_{z_0 K}^{Z} f(z)\, dz = F(Z) - F(z_0).$$

Our next step is to show that the integral along C, where C is any rectifiable curve, is equal to the integral along K, where K is a suitably chosen polygon inscribed in C, also joining z_0 and Z. We accomplish this by showing that the inequality

$$\left| \int_K f(z)\,dz - \sum_{k=0}^{n-1} f(z_k)\,\Delta z_k \right| < \epsilon, \tag{8}$$

where the sum is now taken along the curve C, can always be made to hold for an arbitrarily chosen ϵ by taking Δz_k sufficiently small.

The polygon K now is formed by joining in order, the points of subdivision z_k $(k = 0, \ldots, n)$ of the arc z_0Z of C (Fig. 3). On account of continuity and therefore the uniform continuity of $\varphi(t)$, $\psi(t)$ on the interval $t_0 \leqq t \leqq T$, Δz can be taken small enough to insure that all of the points of K are in that neighbor-

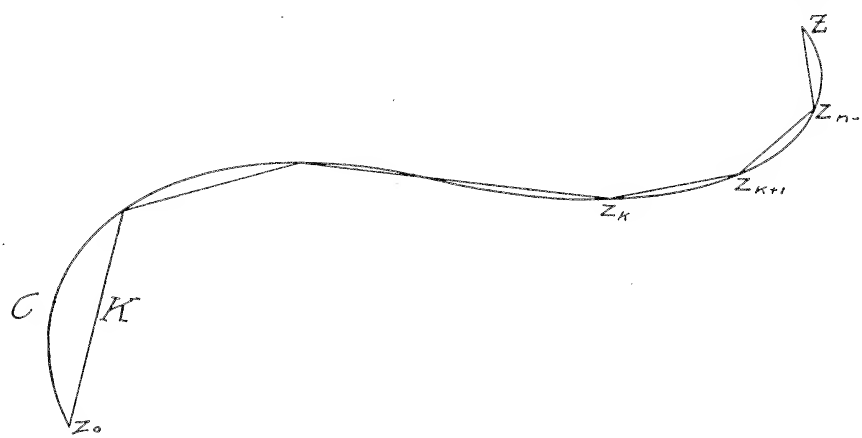


FIG. 3

hood of C where $f(z)$ and $F(z)$ are single valued as indicated in the hypothesis of our theorem. In the expression [8] the term

$$f(z_k)\,(z_{k+1} - z_k)$$

corresponding to the element $z_k z_{k+1}$ is replaced in the integral along K by the expression

$$\underset{n_k=\infty}{\mathrm{L}} \sum_{i=0}^{n_k-1} f(z_{i,k})\,(z_{i+1,k} - z_{i,k})$$

where $z_{i,k}$ are points of subdivision of the line $z_k z_{k+1}$. Since

$$z_{k+1} - z_k = \sum_i (z_{i+1,k} - z_{i,k}),$$

the difference between the integral from z_k to z_{k+1}, taken along the side of the polygon K, and the term mentioned above will be

$$\underset{n_k=\infty}{\mathrm{L}} \sum_i f(z_{i,k})\,(z_{i+1,k} - z_{i,k}) - f(z_k)\,(z_{k+1} - z_k).$$

$$= \underset{n_k=\infty}{\mathrm{L}} \sum_i [f(z_{i,k}) - f(z_k)]\,(z_{i+1,k} - z_{i,k}).$$

On account of the uniform continuity of $f(z)$ in the neighborhood of C specified in the theorem, there exists, for a given ϵ, a δ such that

$$| f(z') - f(z'') | < \epsilon\, L$$

whenever z', z'' are in the neighborhood of C specified in the theorem and

$$| z' - z'' | < \delta.$$

The constant L is the length of the curve. Take

$$| \Delta z_k | < \delta \qquad (k = 0, \ldots, n-1).$$

Then

$$| z_{i,k} - z_k | < | z_{k+1} - z_k | < \delta.$$

and hence

$$| f(z_{i,k}) - f(z_k) | < \frac{\epsilon}{L}.$$

It follows that

$$\left| \sum_i \left\{ f(z_{i,k}) - f(z_k) \right\} (z_{i+1,k} - z_{i,k}) \right| \leqq \frac{\epsilon}{L} \sum_i | z_{i+1,k} - z_{i,k} | .$$

Summing these inequalities for $k = 0, \ldots, n-1$, and taking the limit as the numbers n_k simultaneously approach infinity, we see that inequality [8] follows without difficulty, and we are able to conclude that

$$\int_{z_0 C}^{Z} f(z)\, dz = F(Z) - F(z_0),$$

which establishes our auxiliary theorem.

From these two auxiliary theorems we see that the main theorem stated at the beginning of this section follows at once for a closed curve C when we recall that the function defined in the first of these theorems is single valued.

§4. The Cauchy Theorem for a Curve C in any Simply Connected Continuum

In this section we take up the proof of the main theorem of our paper.

Subdivide the region interior to the simply closed rectifiable curve C lying in a simply connected continuum until each subdivision can be surrounded by a rectangle lying wholly in the continuum (see §1). The integral of $f(z)$ taken around the border of each sub-region exists and has the value zero (§3). The integral of $f(z)$ taken around the curve C is equal to the sum of the integrals of $f(z)$ taken around the border of each of the sub-regions in the sense determined by the direction the integral is taken around C. Thus we have the theorem:

The definite integral

$$\int_C f(z)\, dz$$

exists and has the value zero if the path of integration C is a simply closed rectifiable curve lying within a simply connected continuum on which the integrand function $f(z)$ is single valued, continuous, and possesses a single valued derivative.

The University of Chicago, April, 1913.

THE INFLUENCE OF GLACIATION ON AGRICULTURE IN OHIO[1]

Edgar W. Owen

It is a generally accepted view that glaciation has been of very considerable benefit to agriculture, and that one of its effects has been to greatly increase the fertility of the soil. The purpose of the investigation reported here was to determine the real effect of glaciation on agriculture in certain typical districts along the glacial boundary in Ohio. Detailed comparisons were made of the values of farm products in two regions of central Ohio, which were half glaciated and half unglaciated. An area of 468.24 square miles (149.38 unglaciated), centering about Canton, and including Stark county and parts of Carroll, Summit and Tuscarawas counties, and an area of 430.37 square miles (223.39 unglaciated) about Millersburg, consisting of Holmes and parts of Wayne and Coshocton counties, were chosen. These localities (fig. 1) were taken because in them all other conditions than glaciation, influencing agriculture, were constant throughout each section. The parts of these sections north of Canton and Millersburg were glaciated, whereas the land to the south was unglaciated.

In the Canton or Stark county area the most common outcropping rocks belong to the Pottsville and Allegheny formations, with scattered beds of Monongahela, all of which form soils of about equal suitability for cultivation. The climate and topography, with the exception of the changes wrought in the latter by glaciation, are identical throughout the area. Nearness to market, transportation facilities, drainage (except for differences due to glaciation), and all other conditions effecting this problem, are the same for both the glaciated and unglaciated parts.

The same equality of conditions is noted in the Millersburg or Holmes county district. The prevailing outcrops there belong to the Pottsville and Allegheny, with some Waverly rock showing along the stream courses. The topography in this district is

[1] Report rendered in an advanced course in Geography under the direction of Prof. Frank Carney.

somewhat smoother in both unglaciated and glaciated portions than in the Stark county region.

Detailed information was obtained from the State Agricultural Commission concerning amounts, values and acreage of all farm products in 1912, a typical year. This data was compared on a township and acreage basis for both areas chosen, and a number of methods of comparison were employed to avoid erroneous conclusions, the two areas being used as checks on each other. Townships crossed by the glacial boundary were not considered because of the impossibility of getting reliable data for portions of a township.

The first method of comparison was of the number of bushels, tons or pounds produced per acre, of the more common crops in the different townships. The following results were noted:

				(Bu. per A.)				(Tons per A.)
	wheat	*rye*	*oats*	*corn*	*potatoes*	*apples*	*peaches*	*hay*
Canton area								
Glaciated......	9.9	13.2	43.2	39.1	97.0	37.4	32.8	1.25
Unglaciated....	8.8	15.2	34.3	38.2	99.7	14.0	29.7	1.08
Difference.....	1.1	2.0	8.9	0.9	2.7	23.4	3.1	0.17
In favor of....	Gla.	Ung.	Gla.	Gla.	Ung.	Gla.	Gla.	Gla.
Millersburg area.								
Glaciated......	9.0	11.2	33.7	35.4	94.8	70.4	25.0	1.17
Unglaciated...	10.2	7.6	31.5	37.2	72.8	69.4	23.7	1.10
Difference.....	1.2	3.6	2.2	1.8	22.0	1.0	1.3	0.07
In favor of....	Ung.	Gla.	Gla.	Ung.	Gla.	Gla.	Gla.	Gla.

It is seen that there is a great irregularity in these results. Some crops seem to grow better on the glaciated land, while for others the unglaciated is more favorable. For a number of the crops the yield is greater in the unglaciated part of one section and in the glaciated portion of the other, e.g., wheat and corn. Considering the whole area, the glaciated land seems to have a slight advantage in productivity, which however is not at all general or regular. This would seem to indicate that so far as directly enriching the soil goes, the glacier exerted little or no influence.

The second method of comparison was by figuring the total values for all farm products for each township. Here the true effect of the glacier became manifest. Values were regularly much higher throughout the glaciated townships than in the

unglaciated townships and this was true of both sections studied. The average values per acre (considering total areas, whether cultivated or not), were considerably greater in both of the glaciated portions than in the corresponding unglaciated districts. The following were the results obtained:

	Total values	*Total acreage*	*Value of products per acre*
Canton area			
Glaciated	$5,238,780	204,022	$25.6
Unglaciated	$1,727,169	95,613	$18.1
Millersburg area			
Glaciated	$2,621,592	137,237	$19.1
Unglaciated	$2,348,581	142,980	$16.5

It is seen that this result is just opposite to that obtained in comparing amounts per acre, when only the acreage devoted to the crop considered was included.

The explanation of this seeming discrepancy is found in a comparison of the percentages of cultivated land in the different townships. Regularly throughout the glaciated townships the percentages of cultivated land were much greater than in the unglaciated ones. This is evident from the following figures:

	Average per cent of cultivated land per township	*Average per cent of waste land per township*
Canton area		
Glaciated	68.1	3.9
Unglaciated	32.4	5.3
Difference	35.7	
Millersburg area		
Glaciated	65.2	4.8
Unglaciated	46.4	4.1
Difference	18.8	

In the unglaciated townships a much larger proportion of the land was used as pasture or was wooded. The action of the glacier in smoothing the land and rendering more of the country available for cultivation is plainly shown by these results.

The values of live stock were then compared for all the townships. Sheep were raised much more extensively in the unglaciated areas, due to the great extent of land which was unavailable for much but sheep pasturage. The number and value of all other

FIG. 1. LOCATION MAP, BASED ON A MAP ISSUED BY THE DEPARTMENT OF AGRICULTURE, WASHINGTON.

farm animals were much greater in the glaciated townships because of the greater abundance of good feed other than pasturage.

	Average values per township				
	Horses	*Cattle*	*Sheep*	*Wool*	*Hogs*
Canton area					
Glaciated	$81847	$54098	$1434	$522	$9682
Unglaciated	$56606	$34389	$7810	$3346	$6110
Millersburg area					
Glaciated	$72080	$42582	$5183	$2017	$13357
Unglaciated	$51250	$32997	$7452	$3451	$7291

The above facts appear to warrant the following conclusions:

1. The glacier exerted no great influence on soil fertility, as the comparison of crop yields per acre plainly indicated. In the case of certain crops the glaciated land did seem to be slightly more productive, but this was only in a few cases and was by no means a general or regular result.

2. The glacier did however exert a great influence on agriculture by leveling the surface of the land over which it passed. An examination of the topographic maps of the areas studied shows the glaciated region to be much more even than the unglaciated tracts adjoining, as the front of the glacier marks the boundary between the more regular and the less even surfaces. The percentages of cultivated land in the different areas indicate this leveling effect conclusively, a direct economic consequence of which is seen in the greater value of farm products in the glaciated part than in an equal area of unglaciated land. The value of this glacial smoothing depends upon the nature of the surface before glaciation; the effect would naturally be more marked in rough than in smooth country. It is thus seen that while the ice sheet did not materially effect the fertility of the soil in this region, it was of great economic importance in making more of the land available for profitable cultivation.

THE LOCUST GROVE ESKER, OHIO[1]

JAMES D. THOMPSON, JR.

Among the many forms which glacial deposits assume one of the most striking and interesting is the esker. The winding ridges of glacial origin have long been recognized as distinct features; the term "esker" was applied to them by the geologists of Ireland who noted their occurrence in that country in large numbers. The term "asar" is of Swedish origin and was applied to the same formations as found upon the Scandinavian peninsula.

Among the geologists who did pioneer work on the subject of eskers in this country are such men as N. H. Winchell, I. C. Russel, Warren Upham, G. H. Stone, W. B. Crosby, T. C. Chamberlin, and W. M. Davis. Chamberlin and Davis made especially important contributions bearing on the formation of eskers. Mr. D. Hummel[2] of the Geological Survey of Sweden first suggested the theory that eskers had been formed by sub-glacial stream action. After no little controversy this theory has been generally accepted.

Other Ohio Eskers. Leverett in Monograph XLI of the U. S. Geological Survey describes eleven eskers as follows: (1) The Circleville Esker, Pickaway County, p. 429–431; (2) An esker in Fairfield Township, Huron County, p. 597; (3) The Hartland Esker, Huron County, pp. 615–617; (4) The Leesville Esker, Crawford County, p. 542; (5) An esker near Norwalk, Huron County, pp. 587–588; (6) The Pickerington Esker, Fairfield County, pp. 428–429; (7) The Radnor Esker, Delaware and Marion Counties, pp. 540–541; (8) The Richland Esker, Logan County, pp. 489–490; (9) The Richwood Esker, Union County, p. 540; (10) An esker near Springboro, Warren County, pp. 532–533; (11) The Taylor Creek Esker, Hardin County, pp. 538–540.

Scheffel has described a group of eskers south of Dayton,[3] and Morse one at Columbus.[4]

[1] Work done in a course in Geology, under the direction of Prof. Frank Carney.

[2] James Geikie, *The Great Ice Age,* p. 170.

[3] Scheffel, *Ohio Naturalist,* vol. viii, 1908.

[4] W. C. Morse, *Ohio Naturalist,* vol. vii, 1907, pp. 53–72.

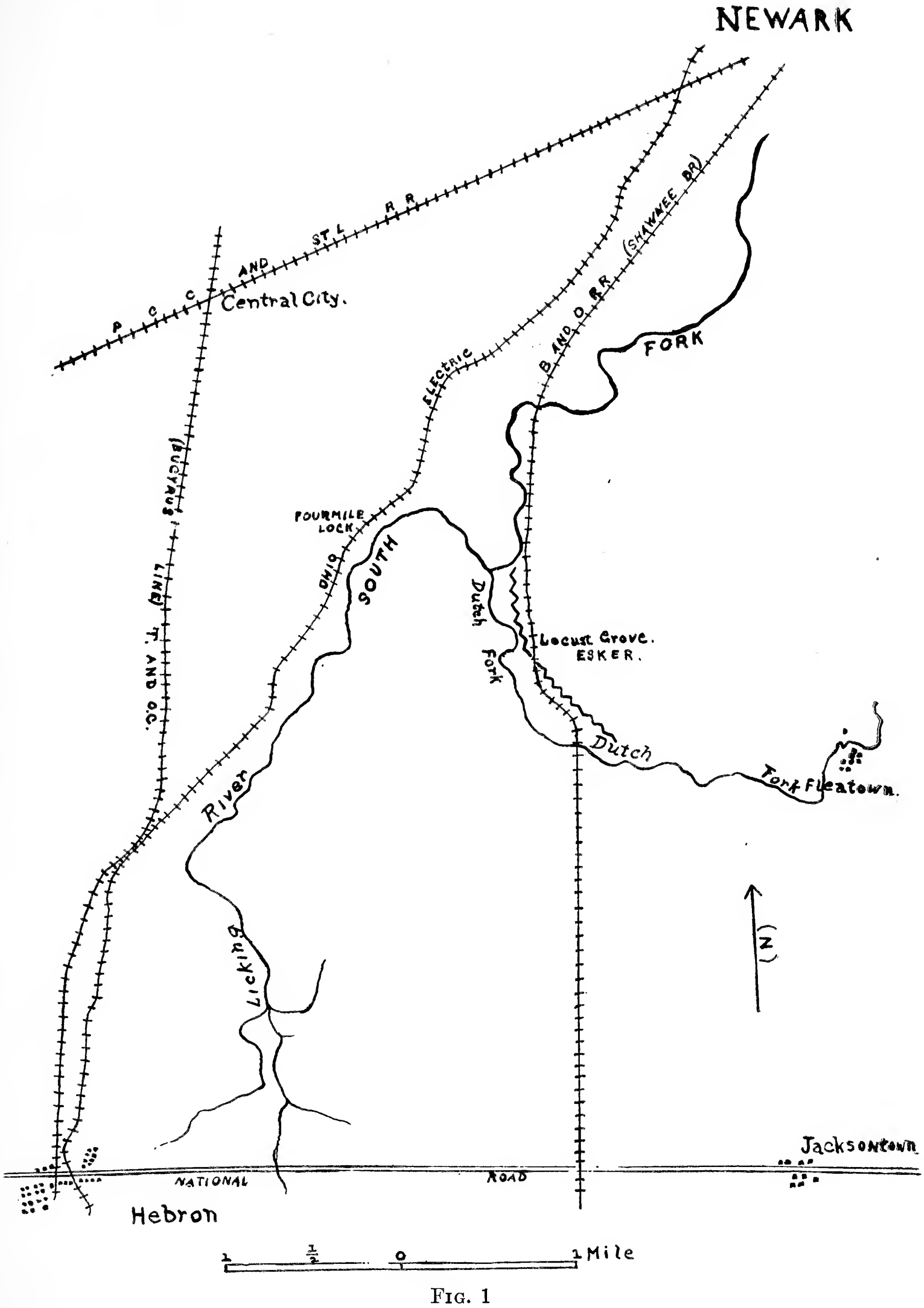
Description. The Locust Grove Esker, approximately three-quarters of a mile in length and oriented S.55°E., is situated about three miles southwest of Newark, Ohio, at Locust Grove on the Baltimore & Ohio Railroad, Shawnee Branch (fig. 1). The esker is in an angle of Dutch Fork, a tributary of the South Fork of the Licking River. On the south it gradually flattens out in the valley bottom, which has been covered over by a layer of silt. A thorough search failed to reveal any continuance of the esker south or southwest of Dutch Fork.

The Locust Grove Esker consists of two main segments, being interrupted about midway between its termini. This interruption does not appear to be due to any post-glacial stream action, as the esker is evidently in its original form. Near its northern end, the esker has been cut away by a small stream flowing into Dutch Fork. The portion of the ridge lying north of this point is low and comparatively flat, and is some 40 or 50 feet in breadth.

The esker is nearly straight, and its main part has an average height of 24 feet 11 inches, the extremes being 30 feet 6 inches, and 21 feet 8 inches. Its width varies from 80 to 100 feet. The southern half of the esker is quite regular in form and gradually flattens out upon the valley floor several hundred feet from the stream. The surface of the northern half of the ridge is irregular. Two very short distributaries and several kettle holes may be noted here also. This part of the esker rests upon a deposit of glacial till which has been deeply cut by Dutch Fork, disclosing a fresh bank some 40 feet high. The entire hill to the top of the esker is 60 feet above water level.

The upper part of this till section disclosed by the river consists of yellow gravelly clay containing a few large stones. In the lower part of this yellow till are masses of bluish clayey material which is evidently partly metamorphosed. The upper till section here exposed is severely weathered and rusted to a considerable depth. At other points close at hand the stream has exposed quantities of the bluish clay which is usually overlain by a few feet of silt. No very fresh unweathered till was observed in the immediate vicinity of the esker.

Although no complete section of the Locust Grove Esker is exposed, the surface and other slight exposures indicate stream deposited drift.



NEWARK
P C C AND ST L R R
Central City.
B AND O R R (SHAWNEE BR)
Electric
Ohio
FOURMILE LOCK
(BUCYRUS LINE) T. AND O.C.
FORK
SOUTH
River
Licking
Dutch Fork
Locust Grove.
ESKER.
Dutch Fork
Fleatown.
N
Jacksontown
NATIONAL ROAD
Hebron
1 ½ 0 1 Mile

Fig. 1

Origin. There are two ice invasions with one of which the formation of the Locust Grove Esker must be associated: the Illinoian and the Wisconsin. Drift from both these invasions occupies the region south of Newark.[5] We find that the drift of the Wisconsin invasion extends out over the Illinoian drift in this area, and in some places we find them intermingled.

The drift of any particular region is always characterised by local material. In some cases it is difficult to determine to which of these two invasions certain drift materials should be attributed. Sometimes we note the Illinoian drift overlain by early Wisconsin drift, which in turn is overlain by later Wisconsin drift.

The till of the Wisconsin invasion is generally composed of yellow gravelly clay, somewhat loose in texture. The later Wisconsin drift is practically unweathered, while that of the earlier periods is more or less weathered and rusted to some depth.

The till of the Illinoian period is also a gravelly clay. Usually where the till is 20 feet or less in thickness, it is yellow in color and shows evidences of prolonged weathering; where thicker than 20 feet the lower part of the Illinoian is generally a bluish gravelly clay, more or less metamorphosed.

Conclusion. The Locust Grove Esker is evidently not of Illinoian origin. The till immediately beneath it, however, is too highly weathered to be of the late Wisconsin period, and we may be justified in concluding that the esker is of early Wisconsin origin.

[5] Leverett, *Monograph XLI*, U. S. Geol. Survey, 1902, pl. XIII.

NOTES ON AGELACRINIDAE AND LEPADOCYSTINAE, WITH DESCRIPTIONS OF THRESHERODISCUS AND BROCKOCYSTIS

Aug. F. Foerste

CONTENTS

1. Introduction

In preparing the descriptions of *Thresherodiscus* and *Brockocystis* it was found necessary to make a study of related genera and species. This led to an accumulation of notes, a part of which are presented in the following pages. Among these are notes on the floor plates and covering plates of the ambulacral rays and on the substomial chamber or cavity in various *Agelacrinidae.* While it has long beeen recognized that a new generic term should be proposed for the Ordovician species usually referred to *Agelacrinus* or *Lepidodiscus,* no new name is offered here since Dr. Bassler is engaged at present on a study of this group.

The writer is under special obligations to Dr. E. O. Hovey, of the American Museum of Natural History, in New York City; to Prof. Stuart Weller, at Chicago University; to Prof. A. D. Hole, at Earlham College in Richmond, Indiana; and to Prof. S. R. Williams, of Miami University, at Oxford, Ohio, for the loan of *Agelacrinidae* from the Museums of which they have charge. Specimens have been borrowed also from the collection of Dr. G. M. Austin, of Wilmington, Ohio.

It has been found possible to determine the systematic position of the fragmentary specimens described by Billings under the terms *Apiocystites tecumseth* and *Apiocystites huronensis,* species whose systematic position hitherto has been in question.

The writer is under obligations also to Dr. R. W. Brock, the

director of the Geological Survey of Canada, under whose auspices he was permitted to make the investigations which led to the discovery of the unique specimens here described under the new generic terms, *Thresherodiscus*, and *Brockocystis*.

2. Character of Surface Used for Support by Ordovician Agelacrinidae

The Ordovician species referred to *Agelacrinus* occur chiefly on *Rafinesquina*. Among 17 specimens of *Agelacrinus cinncinatiensis*, 16 occurred on *Rafinesquina*, and 1 appeared to have been unattached. Among those found on *Rafinesquina*, all were attached to convex surfaces; 13 on the exterior of the pedicel valves, and 3 on the interior surface of brachial valves. Among 26 specimens of *Agelacrinus pileus*, 23 were found on the exterior of the pedicel valves of *Rafinesquina*, 1 appeared to have been unattached, and 2 were attached to bryozoans: one of these bryozoans was *Homotrypa flabellaris*, and the other, *Heterotrypa frondosa*. The types of *Agelacrinus holbrooki*, *Agelacrinus warrenensis*, and *Agelacrinus vetustus* occur on *Rafinesquina*. The type of *Agelacrinus faberi* (plate III, Fig. 4) occurs on the brachial valve of *Hebertella alveata*. The Ordovician *Agelacrini* probably settled on any convenient convex surface on the sea bottom, and the valves of *Rafinesquina* were preferred on account of their comparative smoothness.

3. Orientation of Agelacrinus pileus on Sloping Supports

In the case of the more convex species, such as *Agelacrinus pileus*, with one dextral and four sinistral rays, the orientation of the specimens appears to have been chiefly such as to place the anal interambulacral area on the right side of the sloping surface. For instance, among 24 specimens of *Agelacrinus pileus*, 14 had this anal interambulacral area on the right side of the specimen; in 4, this area was directed diagonally downward toward the right; in 3, it was directly downward and toward the left; in 1, it was directed toward the left; and, in 2, it was directed diagonally upward and toward the left. The direction in which the surface, upon which each individual rested, sloped, was determined in each case by noticing in what direction the specimen of *Agelacrinus*

had sagged (plate II, Fig. 1) on the death of the animal. Toward the upper part of the sloping surface, the peripheral area was broadly expanded by the tension. Toward the lower part of this sloping surface, the peripheral area of the *Agelacrinus* was distinctly narrower, sometimes conspicuously so. The predominance of the cases in which the anal interambulacral area was directed toward the right side of the sloping surface suggests that the orientation preferred by the animal was one which would lift the anal area to about the same level as the oral aperture. The anal area is rarely directed either straight down or straight up the sloping surface, the latter being an extremely uncommon position. The location of the anal interambulacral area on the right side of the sloping support, is shown also by *Agelacrinus holbrooki* (plate I, Fig. 1 D).

The reason for this orientation in the case of *Agelacrinus pileus* and *Agelacrinus holbrooki*, for the present, can be only a subject of speculation. It is noted, however, that among 22 specimens of *Agelacrinus pileus*, 5 rested upon valves of *Rafinesquina* having their anterior margins directed toward the lower part of the slope; 7 rested upon valves with their right anterior or left anterior outlines directed downward; and 6 rested upon valves with the lateral outlines directed downward, so that 18 out of 22 specimens rested upon valves having some part of the convex outline of the valve directed downward. This is the position which specimens of *Rafinesquina* should assume if occurring singly on sea bottoms swept by mild currents. In only 2, among the 22 specimens, was the anterior margin at the top of the sloping surface; and in the remaining 2 this margin faced diagonally upward. Here, again, the slope of the valves of *Rafinesquina* was determined by the direction in which the theca of the *Agelacrinus* had sagged, on the death of the animal.

If, now, it be assumed that the valves of *Rafinesquina* sloped toward the direction of the prevailing currents, some part of the convex outline facing the current, then the thecae of the *Agelacrini*, resting upon the same, usually would be oriented in such a manner as to prevent the excreta, escaping from the anus, from passing across the oral part, or across any considerable part of the area crossed by the ambulacral rays.

It is probable, however, that the orientation of the animal was determined much more by the requirements for food, than by any

efforts to escape contamination by excreta. In this case it is noted that the predominating position of the animal is such as to bring the proximal parts of the left (No. 2) and right (No. 4) rays, and the connecting peristomial slit, into parallism with the direction of the prevailing currents, as determined from the slope of the *Rafinesquina* upon which the animal rested. By the peristomial slit is meant the slit formed by the peristomial plates, which extends from the median line of the left ray to the median line of the right ray (or from plate Z to plate Y in Figure 5B, on plate I). In this orientation, the proximal part of the right ray is directed up the slope. This position of the animal probably accounts for the direction of curvature of the rays in *Agelacrinus pileus*.

4. Curvature of Ambulacral Rays

Some of the early forms of *Agelacrinus*, such as *Agelacrinus billingsi*, Chapman, from the Trenton, and *Agelacrinus bohemicus*, Barrande, from Etage D, have the rays sharp and quite straight, abutting against or tapering to a broad peripheral margin of larger and smaller plates. In another Trenton form *Agelacrinus dicksoni*, Billings, all the rays are strongly curved in a contrasolar direction. This may be regarded as the primitive condition among species with curved rays. The primitive contrasolar curvature of the rays is indicated even by those Ordovician species in which the right ray is strongly curved in a solar direction distally, since, at the proximal end, this ray begins with a contrasolar curvature. This contrasolar curvature of the proximal part of the right (4) ray is well shown by both *Agelacrinus pileus* (plate II, Figs. 1, 2) and *Agelacrinus cincinnatiensis*, and probably was shown also by other Ordovician species of which this part of the theca, at present, is unknown.

The curvature of the rays, whether in a solar or contrasolar direction, was due to the extensionof the distal part of the rays in the effort to secure more food. This extension could not proceed beyond the inner part of the peripheral ring since this was formed by quite large plates, probably held together fairly rigidly. The extension of the rays, of necessity, therefore, took place along the inner margin of this ring. What caused it to start in a *contrasolar* direction is unknown, but the fact is evident.

The development of species with strongly curved rays from those

with moderate curvature is suggested by the ontogeny of *Agelacrinus cincinnatiensis*. In this species, individuals less than 9 mm. in diameter usually have moderately curved rays with the distal part not parallel to the peripheral ring. Specimens 10 mm. in diameter have a small part of the distal extremity parallel to the ring. In successively larger specimens, a larger and larger part of the distal extremity becomes parallel to the peripheral ring, until in mature specimens, this feature becomes conspicuous. Similar derivation of curved rays from comparatively straight rays have been shown in the ontogeny of *Agelacrinites hamiltonensis* and *Agelacrinites buttsi*, by Clarke, in New Agelacrinites, plate 10, Figs. 6, 7, 8, and 9, in 1901.

5. Cause of Reversal of Curvature of Right Posterior Ray

The cause of the reversal of curvature from contrasolar to solar, of the right posterior(No. 5) ray is unknown. Any attempt to solve the problem must, for the present, again be a subject merely of speculation. Possibly this reversal of curvature is connected with the orientation of the specimen. Even in the living state, the position of the animal on a slanting surface would tend to increase the tension along the upper part of the margin and just within the adjacent part of the peripheral ring. If, at the same time, the anus were dragged slightly downward and toward the left, the proximal part of the right ray (No. 4) being directed up the supporting slope, then the greatest tension would be on the upper, right hand side of the inner curve of the peripheral ring, possibly sufficiently below the distal part of the right posterior ray (No. 5), in young specimens, to loosen the contact between this part of the peripheral ring and the immediately adjacent part of the posterior or anal interambulacral area, and thus to admit of the curvature of the right posterior ray in a solar, rather than a contrasolar direction.

In the case of *Agelacrinus cincinnatiensis*, such a drag of the anus downward and toward the left is suggested by the presence usually of several small plates along the upper margin of the anal pyramid, the proximal part of right ray (No. 4) being directed upward. In one specimen of *Agelacrinus cincinnatiensis*, No. 13266-1-b, belonging to the American Museum of Natural History, these small plates are specially numerous along the upper

right hand side of the anal pyramid, and similar features are presented by the specimen of *Agelacrinus holbrooki* which was figured by Clarke (*New Agelacrinites*, p. 189, Fig. 2, 1901; see also plate I, Fig. 1C, of this BULLETIN), in which the small plates also are specially numerous along the upper right hand margin of the anal pyramid, if the specimen be oriented so as to direct the proximal part of the right ray (No. 4) toward the top.

In specimens of *Agelacrinus cincinnatiensis* in which the supplementary small plates along the upper right hand margin of the anal pyramid are either absent or few, the distal part of the right posterior ray (No. 5) usually is parallel to the peripheral ring and terminates opposite the middle of the anal pyramid. In specimens in which the supplementary small plates are numerous along the upper right hand margin of the pyramid, for example, in specimen No. 13266-1-b, cited above, the tip of the right posterior ray curves distinctly, at the very extremity, away from the peripheral ring, toward the anal pyramid. In typical *Agelacrinus holbrooki*, also with numerous supplementary plates along the upper right hand margin of the pyramid, the tip of the right posterior ray curves still more strongly and terminates above the level of the anal pyramid (plate I, Fig. 1D), the specimen being oriented, as before, so as to direct the proximal part of the right ray (No. 4) toward the top. In this case, also, it will be noted that a few smaller sized plates occur on the inner or concave sides of the distal parts of some of the other rays of *Agelacrinus holbrooki*, possibly owing to crowding.

In *Agelacrinus pileus*, no supplementary smaller plates were noticed along the margin of the anal pyramid, and no evidence is here suggested of any cause for the reversal of curvature of the right posterior ray, from contrasolar to solar.

6. Reversal of Curvature in Streptaster

No cause of the reversal of curvature of the right posterior ray of *Streptaster reversata* (plate IV, Fig. 3), described in this paper, is suggested by any detail of structure noted so far. The two species of this genus, previously described, have all the rays curved in a contrasolar direction.

7. Supporting Surface of Agelacrinus Cincinnatiensis Probably More Horizontal than in A. Pileus

An examination of a number of specimens of *Agelacrinus cincinnatiensis* has failed to bring out as strong a connection between the orientation of the individuals and the direction of the slope upon which these individuals were located, as was noted in the case of *Agelacrinus pileus,* and *Agelacrinus holbrooki.* *Agelacrinus cincinnatiensis* is a larger and flatter species than *Agelacrinus pileus.* The former frequently attained a diameter of 30 mm., occasionally of 33 or even 35 mm. The latter usually did not exceed 15 mm. in diameter, although specimens 20 mm. in diameter have been noted. The specimens of *Agelacrinus cincinnatiensis,* being of larger size, covered a much larger part of the valves of the *Rafinesquina* upon which they rested, and, therefore, were not likely to find a sufficiently large surface unless the valve was more or less horizontal, and not partly imbedded in the mud on the sea bottom. A moderate amount of sagging of the theca, after death, however, was noted. In these cases, the upper part of the peripheral outline is flattened and extended, while the lower part of this outline is shortened, as in *Agelacrinus pileus,* but to a less marked degree.

8. Solar Curvature in the Devonian Agelacrinites and Lepidodiscus

The preceding remarks are based upon an examination of the Ordovician specimens referred to *Agelacrinus* or *Lepidodiscus.* They do not take into account the Devonian *Agelacrinites hamiltonensis,* with both the right (No. 4) and the right posterior ray (No. 5) solar (plate VI, Fig. 3), or *Lepidodiscus alleganius,* with all the rays solar (plate VI, Fig. 2A). The remarks evidently are based on highly speculative inferences, but they at least suggest that some of the characteristics of various species of *Agelacrinus,* may be produced by the orientation of the animal while resting upon some support, especially while engaged in feeding. It may be assumed that the main business of the animal while in life consisted in feeding.

9. Aboral Surface of Lepidodiscus

The oral part of the specimens being at the center of the exposed part of the theca, that part of the theca of the various *Agelacrinidae* which rested upon some shell or other support may be known as the aboral surface. It is probable that this aboral surface varied considerably in different genera, but nothing is known of it excepting in very few species. Clarke, in *New Agelacrinites*, has figured the aboral surface of two specimens of *Lepidodiscus alleganius*. From these specimens it is evident that this *Lepidodiscus* was derived from some more or less globular or oval ancestor covered by imbricating scaly plates which overlapped in a direction from the base toward the upper or oral end. There is no indication of the animal having become attached to a support even temporarily. (Plate VI, Fig. 2B.)

10. Mobile Marginal Part of Peripheral Ring

In all of the Ordovician species referred to *Agelacrinus* or *Lepidodiscus*, however, the animal evidently was capable of attaching itself to various objects for support, although this attachment was not permanent, and occasional specimens are found unattached. The main means of attachment evidently was the margin of the peripheral ring, since the latter always is composed of small plates, closely adjusted to the varying curvature of the underlying support. These small marginal plates are merely the protective covering of the underlying soft fleshy margin of the individual, the close application of which to the underlying *Rafinesquina* or other support permitted the attachment. The slight elevation of the central part of the aboral surface evidently caused the latter to act like an ordinary sucker.

The ready mobility of the marginal part of the peripheral ring is suggested not only by the close application of the latter to the underlying support, but also by the sagging of the specimen, on death and probably also, to a certain extent, during the life of the animal. To this sagging frequent reference has been made in the preceding lines. The fact that some specimens are found unattached also suggests that, when attachment again was desired, the animal was able again to apply this margin of the peripheral ring to the varying curvature of the underlying object sufficiently

closely to secure support. It is inconceivable that this close application of the margin of the peripheral ring could be accomplished if the latter were underlaid by imbricating scales. Therefore, imbricating scales are believed to have been absent at least from that part of the aboral surface which underlaid the margin of this ring.

11. Rigid Inner Band of Peripheral Ring

In agreement with the ready mobility of the marginal part of the peripheral ring, this part is covered with small imbricating plates arranged in diagonal rows. These increase in size toward the inner part of the peripheral ring, forming an inner band of strong plates, usually elongated transversely, or at least so imbricated as to expose only the wide upper margins of the plates. This inner band of large plates rarely has suffered deformation, suggesting that here the plates were held together more or less rigidly. In fact, while the interambulacral surfaces frequently are found sagged below the level of the inner margin of this peripheral band, after the death of the animal, and while even the distal parts of the rays not infrequently give evidence of sagging (see, for instance, Fig. 1, on plate II), the inner band of the peripheral ring usually retains its form. It remains undisturbed even in specimens in which almost all the interambulacral and ambulacral plates are disarranged. The surfaces of these plates of the inner band of the peripheral ring usually are closely applied to each other, forming a rigid circle of plates.

12. Vertical Ridges on Plates of Inner Band of Peripheral Ring

In a specimen of *Agelacrinus* belonging to the American Museum of Natural History, forming No. 13266-1-r of that collection (plate I, Fig. 6E), the under side of the upper or oral face of the theca is exposed. The species is assumed to be *Agelacrinus pileus* on account of the strong convexity of the theca, and its comparatively small diameter: 20 mm. This specimen suggests that not only all of the smaller plates belonging to the marginal part of the peripheral ring, but also the lower margins of the outer two rows of the inner band of much stronger plates, could be brought close

to the underlying surface. The plates belonging to the two outer rows of the inner part of the peripheral band are characterized by the presence of three short ridges. These ridges are found near the basal margins of the plates. In length they vary from four-fifths of a millimeter to less than half a millimeter; and they are equally spaced, the three occupying a width of four-fifths to one millimeter. In direction they vary from approximately vertical to moderately radiating in an upward direction. They fill in the spaces between the adjacent plates belonging to the next inner circle of large plates forming the inner band. They may be merely space fillers, assisting in holding these plates of the inner band rigid, but they may also be points of attachment for muscles. They do not fit into grooves on the distal faces of the adjoining plates of the inner band. These ridges were noted by Meek, presumably in a specimen of *Agelacrinus faberi*, identified by Meek as *Agelacrinus cincinnatiensis*, found by L. B. Case in the upper part of the Richmond group, at Richmond, Indiana. This specimen seemed to have grown on a valve of *Byssonychia*, and exposed the under surface of the oral face of the theca. Regarding this specimen Meek stated: "The disc plates near the outer margin show, on their inner surfaces, little parallel ridges, directed inward, and apparently fitting into corresponding furrows in the lapping edges of the contiguous pieces." I doubt the presence of this corresponding furrows but have not seen the specimen. On specimen 13266-1-s, (plate I, Fig. 6D), belonging to the American Museum of Natural History, there are two thecae of *Agelacrinus pileus*. Of these, one is considerably dismembered and exposes the inner surface of two of the plates belonging to the inner band of the peripheral ring. Here, again, short vertical ridges, 0.4 mm. in length, project from the lower margin of the plate. On one of these plates the vertical ridges occupy a total width of 1 mm.; on the other, of 1.3 mm. They evidently never fitted into grooves in the next inner set of plates.

13. Central Part of Aboral Surface

No definite information has been secured regarding the central part of the aboral surface of the theca, within the space limited by the peripheral ring. Possibly the under side of the oral face of the theca of *Agelacrinus pileus*, figured by Miller and Faber, No.

8825 of the Faber Collection, in Walker Museum, at Chicago University, preserves traces of thin plates belonging to the aboral surface, but I have interpreted these plates as displaced floor plates of the ambulacral rays. Specimens of *Agelacrinus cincinnatiensis*, in which a few of the plates of the oral side of the theca are missing, are not uncommon. On etching away, with caustic potash, the clay filling between this oral face of the theca and the surface of the *Rafinesquina* upon which it rested, no trace of aboral plates were discovered. The finest transverse lines, on the radiating striae of the *Rafinesquina*, however, were preserved. While this evidence is only negative, it may be assumed that in those forms which assumed the sessile habit, the original plates on the aboral surface became obsolete, a fleshy surface, unprotected beneath, being much better adapted for attachment to an underlying surface.

14. Interambulacral Plates

In all of the Ordovician species referred to *Agelacrinus* or *Lepidodiscus*, the interambulacral plates are scale-like and more or less imbricating, overlapping each other in a proximal direction. The degree of overlapping of some of the plates may be small but nevertheless is distinct. It is always greater toward the peripheral band. Even in *Agelacrinus holbrooki* (plate IV, Fig. 1), which Clarke describes as showing mosaic plates in the interradii, while squamose and imbricating at the margin (*New Agelacrinites*, 1901, p. 189), the interambulacral plates overlap proximally at quite acute angles although not for long distances. This is best seen where the plates are more or less loosened but not displaced.

The plates are arranged more or less in rows crossing each other diagonally. This diagonal arrangement continues into the adjacent rows of plates belonging to the peripheral ring.

In view of the theory that the *Agelacrinidae* represent derivatives from a Cystidean ancestry, the imbricating squamose form of plates can scarcely be considered as primitive. The plates of Cystideans are polygonal and form a mosaic, and it is from a polygonal, mosaic stock of plates that those of the *Agelacrinidae* may be supposed to have originated.

The change to imbricating plates probably was due to the assuming of the sessile habit, together with the enormous shortening of the theca in a vertical direction. This caused the distal edge

of one plate to collapse within the proximal edge of the adjoining plate, especially along the margin of the sessile theca, at the peripheral ring. Even in the interambulacral areas, the overlapping is always greater toward the peripheral ring than toward the mouth, as already stated. The imbrication probably began at the peripheral ring, and then progressed proximally to areas nearer and nearer to the mouth.

In that case such species as the Devonian *Agelacrinites hamiltonensis* may be regarded as merely forms in which the imbrication had not proceeded far from the margin of the thecal disc.

In *Streptaster*, the interambulacral plates are small, polygonal in outline, and form a mosaic. In *Streptaster vorticellatus*, these plates are well known near the distal end of one of the interambulacral areas, where they are about half a millimeter in diameter, and form an irregular mosaic of polygonal plates. In *Streptaster reversatus* (plate IV, Fig. 3), the polygonal plates in the area between the left and left posterior rays are even less than half a millimeter in diameter, but in the posterior or anal interambulacral area, where the mosaic of plates consists of an irregular mixture of large and small plates, some of the larger plates attain a diameter of almost 1 mm. In all species of *Streptaster*, the plates forming the inner band of the peripheral ring are strongly imbricating.

In *Hemicystites* the interambulacral plates are squamose and imbricating. In the closely related *Cystaster*, they are rounded or polygonal, and form a mosaic, although the individual plates are of minute size, averaging one-fourth of a millimeter in diameter.

In *Thresherodiscus* (plate III, Fig. 3), the larger interambulacral plates all are squamose and imbricating. The smaller plates, along the lateral margins of the rays, also overlap in a proximal direction, but in a less evident manner.

Theoretically, the earlier forms of *Agelacrinidae* should show less imbrication among the interambulacral plates than the later forms. As a matter of fact, this is not verified by the specimens found so far. Both the imbricating and the mosaic type of interambulacral plates occur in the Trenton, and the oldest species known at present have imbricating interambulacral plates. However, none of these Trenton forms can be regarded as very primitive.

15. Trimerous Origin of Ambulacral System

The ambulacral system of the *Agelacrinidae* evidently is of trimerous origin, although a pseudo-pentamerism has been superinduced upon the same. This pseudo-pentamerism is indicated by the fact that in all Ordovician species referred to *Agelacrinus* or *Lepidodiscus*, rays 1 and 2 (left posterior and left, respectively) and also rays 4 and 5 (right and right posterior) separate from each other at a greater distance from the center than ray 3 (anterior ray). A far more striking illustration of pseudo-pentamerism among the *Agelacrinidae*, however, is given by the *Thresherodiscus ramosa* (plate III, Fig. 3, and Fig. 1 on page 434). Here the trimerous origin of the rays is so evident that it is necessary to number the rays as in the pseudo-pentamerous species of *Agelacrinus* merely to admit of ready comparison with the latter. In *Thresherodiscus*, the ambulacral system originates at the center in three arms, left, anterior, and right, each of which branches dichotomously at a distance of about 2 mm. from the center of the peristomial area, further branching taking place, also in a dichotomous manner, distally. While it was scarcely necessary to discover this genus in order to demonstrate the trimerous origin of the ambulacral system of the *Agelacrinidae*, it must be admitted that *Thresherodiscus* offers a striking confirmation of this origin.

16. Cover Plates of Ambulacral Rays

The cover plates of the *Agelacrinidae* usually are well preserved. In *Agelacrinus pileus* (plate II, Figs. 1, 2), there are two series of cover plates, one on each side of the median line of the ray. In by far the greater number of specimens the proximal side of each cover plate is elongated into an acute spinous tooth which projects across the median line of the ray and interlocks with the opposing cover plate (plate I, Fig. 5A, B, C, also plate II, Fig.1). The latter also has a spinous prolongation on the proximal side, and both cover plates are curved concavely on the distal side of this spine, along the median line of the ray, so as to admit the interlocking. In a few specimens, apparently of the same species, this spinous prolongation is absent or inconspicuous, and the cover plates on opposite sides of the median line of the ray, oppose each other like two series of V's, with their apices alternating (plate II, Fig. 2).

In *Agelacrinus cincinnatiensis,* and in the closely related *Agelacrinus holbrooki* (plate I, Fig. 1C), four series of cover plates are present, two series on each side of the median line of the ray. Of these series, the two outer ones are here called the lateral coverings plates, and the two inner series, intercalated along the median line are called the median or intercalated covering plates. The exposed part of the lateral covering plates are triangular in form, the apices being directed toward the median line; they are of larger size and rest upon the lateral margins of the floor plates. The median or intercalated covering plates are of smaller size and only their tips may be seen, intercalated between the tips of the lateral covering plates, and about equalling the latter in number. Along the ambulacral groove these plates are probably ridged vertically, so as to interlock and also so as to prevent their lateral displacement.

In some of the specimens of *Agelacrinus pileus,* the lateral covering plates differ considerably in size and form, some of them being longer and narrower and approaching the palisade-like effect of *Streptaster*. In these cases the conspicuous elongation is in all cases along the inner or concave curvature of the distal parts of the rays. This projects the median line of the ambulacral ray farther toward the periphery of the theca, and perhaps enlarges the effective feeding area of the animal.

In *Streptaster*, the palisade-like elongation of the covering plates receives its greatest expression. Here (plate I, Fig. 7B, plate IV, Fig. 3), only two series of covering plates are in evidence, one on each side of the median line of the ray. Here, also the tips of the plates interlock by a prolongation of the proximal side of the covering plate into an angulation which fits into a recession located more distally, on the opposing plate. This interlocking may, at first glance, be obscured by the truncated appearance of the tip of the plates, but is shown by all well preserved specimens. If any median or intercalated covering plates were present, the latter must have been very small, and at least have not been identified so far. For the present, *Streptaster* is regarded as related more closely to *Agelacrinus pileus* than to any other known Ordovician species, but it is sufficiently distinguished by the presence of a mosaic of small polygonal plates, quite irregularly arranged, in the interambulacral areas.

In *Thresherodiscus ramosa* the median or intercalated cover-

ing plates are at least as numerous as the lateral covering plates, in some parts of the specimen apparently exceeding the latter in number (plate I, Fig. 8). It is the median covering plates which, in this species, interlock along the median line of the rays, since the lateral covering plates do not reach this line.

It may be noted that even in *Agelacrinus cincinnatiensis* a third series of still smaller plates may be intercalated on each side of the median line, occasionally, producing a very serrate appearance along this line.

In *Cystaster granulatus* each ray has about eleven pairs of covering plates. As in *Agelacrinus pileus,* the spinous prolongation of each covering plate is on the proximal side of the tip. The covering plates are flattened, and the upper parts of the flattened surfaces are inclined distally, or away from the center of the specimen.

17. Peristomial Plates

The peristomial plates of *Thresherodiscus* do not appear to differ conspicuously from the other covering plates. They are not well preserved, but such traces as exist suggest merely a continuation of the series of median and lateral covering plates of the rays also along the peristomial slit. The term peristomial slit is used here for the median line between the covering plates of the ambulacral system along that part which extends across the oral aperture, from the point of bifurcation of rays 1 and 2 (left posterior and left rays) to the point of bifurcation of rays 4 and 5, (right and right posterior rays). In this lack of differentiation of the covering plates in the peristomial region from those on the rays, *Thresherodiscus* resembles the more primitive conditions in the *Cystidea.*

The peristomial plates of *Agelacrinus pileus* (plate I, Fig. 5B, also plate II, Figs. 1, 2) are highly differentiated from those of the rays. In all specimens there is a right anterior (R) and left anterior (L) peristomial plate. These are rhomboid plates, sufficiently extended along their greater diameters to prevent the base of the anterior ray from coming in contact with the base of the right and left rays. Of these, the right anterior rhomboid plate always is taller, so that the first covering plate of the anterior ray is found on the left side of the median line. On the posterior side of the peristomial slit there is a single large plate (P), often

described as quadrangular, but in reality quite irregular in form. Rays 1 and 2 (left posterior and left rays) are separated by a long narrow plate (Z), equally common to both. If this plate not be taken into account, then the first covering plate of the left ray (No. 2) is found on the anterior side of the median line, and the first covering plate of the left posterior ray (No. 1) is found on the posterior or contrasolar side of the median line of this ray. In a similar manner, there is a long narrow plate separating rays 4 and 5 (Y). If this plate not be taken into account, the first covering plate on the right ray is found on the anterior side of the median line of this ray, and the first covering plate of the right posterior ray is found on the posterior or solar side of the median line of this ray.

There is a tendency toward differentiation in form of the first covering plate of the right posterior ray, as defined above. This differentiation is connected with the form of the posterior peristomial plate, and consists in a slight elevation of the basal margin of the covering plate, corresponding to a much more marked raising of the lower right-hand margin of the posterior peristomial plate (P). Usually the first covering plate of the right posterior ray (No. 5) fits snugly against the upper part of the right hand margin of the posterior peristomial plate, often having a convex outline where adjoining the latter, but posteriorly these two plates do not fit as closely to the anterior outline of the immediately adjacent interambulacral plate (X). This suggests the possibility of the exit of some duct at the angle between these three plates (P, X, and 5). No aperture actually penetrating a plate has been noted.

In *Agelacrinus cincinnatiensis*, there is either less constancy in the form and arrangement of the peristomial plates or the peristomial areas of the specimens at hand are not infrequently more or less distorted, and the plates more or less broken. The original of Figure 7, on plate 6, of the *Twenty-fourth Annual Report of the New York State Museum of Natural History*, is by no means as distinctly defined a specimen as the drawing suggests. Many of the details, including those of the peristomial plates, unquestionably were transferred from other specimens, the identity of which is unknown. The plates of the interambulacral areas, with the exception of those on the right side of the specimen, are less numerous than figured. The peristomial plates, and some of the

adjacent plates, are badly weathered. As far as may be determined from all the specimens at hand, the peristomial plates of *Agelacrinus cincinnatiensis* agree with those of *Agelacrinus pileus* in the presence of a rhomboid left anterior plate, a rhomboid right anterior plate, and an irregular, so-called quadrangular, posterior plate; along the lower part of the right hand margin of the latter the border is raised, and at the angle at which the posterior plate is joined by the first lateral covering plate of the right posterior ray and by the adjacent interambulacral plate, there may have been the opening of some duct. However, the long, narrow plates, which in *Agelacrinus pileus* are intermediate between rays 1 and 2, and between rays 4 and 5, have not been identified, and the first covering plate on the contrasolar side of the left posterior ray, in *Agelacrinus cincinnatiensis*, frequently is long and narrow, and parallel to the adjacent oblique left margin of the posterior peristomial plate, instead of resembling the immediately following lateral covering plates of the same ray, as in *Agelacrinus pileus*.

The peristomial area of *Streptaster* is unknown. Judging from the close similarity of the covering plates in some of the specimens referred to *Agelacrinus pileus* to those of *Streptaster* it is suspected that, when the peristomial plates of *Streptaster* are known these also will be found similar to those of *Agelacrinus pileus*.

In *Cystaster granulatus*, the various peristomial plates recognized in *Agelacrinus pileus* (R, L, R, Y, Z, in Fig. 5B, on plate I) may be identified. The two anterior peristomial plates are strongly V-shaped. The posterior peristomial plate also is strongly grooved along the median line, as though it originally consisted of two distinct plates.

18. Floor Plates of Devonian and Carboniferous Agelacrinidae

The plates beneath the ambulacral grooves are known as the floor plates. These floor plates have been known hitherto from only a few species among the *Agelacrinidae*.

In *Haplocystites rhenana*, Roemer, from the lower Devonian of the Rhine, there was only a single row of these floor plates. The species has been refigured by Jaekel (*Stammesgeschichte der Pelmatozoen*, 1899, plate III, Fig. 3), and, according to Clarke, is so closely related to the American *Echinodiscus* or *Lepidodiscus*, that eventually the name *Haplocystites* may displace one of these terms.

The floor plates of *Agelacrinites beecheri* (plate I, Fig. 2). from the lower Carbonic (Olean conglomerate) of Warren, Pennsylvania, are figured by Clarke (*New Agelacrinites*, 1901, p. 195, Fig. 6) as also arranged in a single row, the plates overlapping each other distally, as seen from below.

19. Floor Plates of Ordovician Species Referred to Agelacrinus

Meek, in describing *Agelacrinities cincinnatiensis* (*Ohio Paleontology*, vol. i, p. 55, in 1873) refers to a specimen, a little more than an inch in diameter, found by L. B. Case at Richmond, Indiana, in the upper part of the Richmond group. Judging from the horizon, this specimen may have belonged to *Agelacrinus faberi*, which was described from the same locality and horizon. Regarding this specimen Meek stated: "The inner side of each arm or ray is here seen to be composed of a single series of quadrangular pieces that are not imbricating."

Miller and Faber, in describing the lower surface of the upper side of the theca of a species of *Agelacrinus*, identified as *Agelacrinus pileus* (*Journal of Cincinnati Society of Natural History*, vol. xv, p. 85, plate I, Fig. 10, in 1892; see also plate I, Fig. 5A and plate II, Fig. 4 in this Bulletin), made the following statements, to which are added, in brackets, such explanatory terms as are deemed necessary for a ready understanding of the descriptions given.

The under side of the rays, as seen from below, consist of a row of plates on each side of the furrow (the covering plates), which interlock at the bottom of the furrow (as seen from below), and are, therefore, without reference to abutting (interambulacral) imbricating plates, pentagonal instead of quadrangular, as Meek described them. (Meek described the floor plates as quadrangular, while Miller and Faber had the covering plates in mind when they described the latter as pentagonal.) They (the bases of the covering plates) extend beyond the margin of the (interambulacral) imbricating plates into the visceral cavity (for a distance equal to) half the depth of the ambulacral furrows (as seen from below), and are separated from each other, in their extensions laterally into the visceral cavity, so as to present a strongly serrated edge, as shown in the illustration (loc. cit., plate I, Fig. 10; see also plate I. Fig. 5A of this Bulletin). The furrows (as seen from below) are covered with thin nonimbricating plates (floor plates), that do not cover the serrated edges above described. Part of the covering (consisting of the floor plates) is preserved in our specimen as shown in the illustration, on two rays (anterior and left rays), but the plates are so small and the

sutures so indistinct, that they could not be shown, except in a greatly magnified view. (It is evident that Miller and Faber regarded the floor of the ambulacral groove as made of a mosaic of numerous minute plates, instead of a single row of large plates, as is, more likely, the fact.) The coverings of the rays are united near the center of the fossil by a subpentagonal rim.

The specimen described by Miller and Faber forms No. 8825 of the Faber Collection, in Walker Museum, at Chicago University. It was found near the top of the hills, at Cincinnati, Ohio, probably in the Corryville member of the Maysville. It is evident that Miller and Faber did not recognize in this specimen the presence of a single row of floor plates.

In the figured specimen, however, the transverse sutures between the floor plates can be distinguished under favorable illumination (plate I, Fig. 5A). As seen from below, the floor is evenly convex in a transverse direction, three floor plates occurring in a length of 2 mm. along the proximal extremity of the anterior ray, and two floor plates, within almost the same length, along the proximal extremity of the left ray. In this specimen, figured by Miller and Faber, the floor plates appear to have a width of about 1.5 mm. and apparently permit the basal extensions of the covering plates, which produce the serrated appearance described by Miller and Faber, to project beyond their margins. I have seen other specimens of *Agelacrinus pileus*, however, in which the floor plates were thicker, and in which they appeared to underlie the entire width occupied by the covering plates, including their basal extensions, so that further investigation on this point is desirable.

In the American Museum of Natural History there is a small *Agelacrinus* (plate II, Fig. 3), numbered 13266-1-x, and obtained at Cincinnati, Ohio. It is only 12 mm. in diameter and evidently is a young specimen. It is assumed to be a young specimen, and is remarkable in showing the under surface of the upper face of the theca with remarkable clearness. In this specimen the floor plates are distinctly defined. They evidently form a single row, are much wider than long and give no evidence of the projection of the basal extension of the covering plates beyond the lateral margins of the floor plates.

Similar features are shown also by *Agelacrinus austini*, from the upper part of the Whitewater member of the Richmond, on Dutch creek, northwest of Wilmington, Ohio. Plate VI, Fig. 1B.

The presence of floor plates is readily verified among Ordovician species referred to *Agelacrinus* and *Lepidodiscus*, provided that the overlying cover plates are carefully removed. They are seen also frequently among the displaced plates of specimens which had more or less disintegrated before being covered by the sea sediment.

In the Geological Museum of Ohio State University, there is a specimen of *Agelacrinus cincinnatiensis*, showing a series of three floor plates in a single row (plate I, Fig. 6C). In this case it is evident that the median part of each plate, as seen from above, was depressed into a wide groove, while a narrow groove extended lengthwise along the border, on each side of the wide median groove. The wide median groove evidently formed part of the ambulacral furrow, while the narrow lateral grooves had some connection with the fulcra of the lateral covering plates, by means of which the latter were opened and closed over the ambulacral furrow.

In the type of *Agelacrinus faberi*, forming No. 8821 in the Faber Collection in Walker Museum, at Chicago University, possibly identical with the species from which Meek described the presence of floor plates, a few floor plates were identified (plate I, Fig. 3C), and plate II, Fig. 4), among the mixture of plates there presented. Three of these floor plates occurred in a single row. Little could be learned from them beyond the fact that these plates are widely grooved along the top, as though the plates were almost evenly concave. They evidently overlapped a little in a proximal direction, as seen from above. The narrow lateral grooves, one on each side of the broad median groove, could not be identified. They may have been present formerly, but the floor plates are badly weathered.

In the type of *Agelacrinus holbrooki*, forming No. 1004, in the James Collection, in Walker Museum, at Chicago University, a series of five floor plates belonging to the left ray (No. 2) are preserved (plate I, fig 1E). Of these, the three floor plates which belong to that part of the ray which is parallel to the peripheral ring, show a comparatively narrow median ambulacral groove, and unusually strong lateral grooves which have some connection with the articulation of the lateral covering plates. In the case of two other plates belonging to the same series, but located nearer the proximal end of the ray, the median, ambulacral groove was much

wider, and there was no indication of lateral grooves. The basal extensions of several of the lateral covering plates, however, were in evidence, and apparently extended beyond the lateral margins of the floor plates. However, since all the floor plates are badly weathered, further evidence is needed on this point. While the basal extensions of the lateral covering plates undoubtedly pass beneath the margins of the adjacent interambulacral plates, it is very likely that these extensions are enclosed, from beneath, by the floor plates, the total width of which probably was greater than suggested by the specimen described by Miller and Faber.

20. Floor Plates of Streptaster

In a specimen of *Streptaster*, found in the upper part of the Whitewater member of the Richmond, about three miles west of Dayton, and regarded as a normal specimen of *Streptaster septembrachiatus*, Miller and Dyer, the most striking feature is the extreme narrowness and considerable height of the ambulacral rays, and the tall, narrow lateral covering plates (plate I, Fig. 7B; also plate IV, Fig. 2) looking like an uninterrupted series of more or less vertical palisades. The enclosed ambulacral cavity is high, but evidently very narrow. The upper ends of the lateral covering plates are blunt, as seen from above. The bases of the covering plates on opposite sides of the rays practically must be in contact with each other. This is seen readily on viewing the rays from beneath.

All the rays are contrasolar. The lateral covering plates rest upon the floor plates—two lateral covering plates on each floor plate, one covering plate on each side of the floor plate. The widest floor plate is barely 1 mm. in width, and this leaves very little space for the ambulacral groove. All five of the ambulacral rays are exposed on the lower surface of the oral face of the theca, and, from this point of view, in all five rays, the floor of the ray consists of a single longitudinal row of floor plates (plate I, Figs. 7A, B), thinning and overlapping in a distal direction, forming angles of about 30 degrees with the former flat base of the theca. It is evident that if the floor plates could be seen from above, the proximal end of one would be found overlapping the distal end of the next, as in all other *Agelacrinidae* in which the floor plates are known. The upper, proximal side of the floor

plate is flattened in a direction parallel to the base of the theca, and this flattened surface supports the lateral covering plates, as already mentioned.

Such traces of the interambulacral plates as remain are seen only from below and are not clearly defined. They, no doubt, were small and polygonal, forming an irregular mosaic as in other species of *Streptaster*.

21. Floor Plates of Thresherodiscus

In *Thresherodiscus ramosa*, the floor plates also occur in a single row (plate I, Fig. 8; also plate III, Fig. 3). The median third of each plate is occupied by a comparatively shallow ambulacral groove. The lateral thirds of the plates are comparatively flat. These lateral parts probably were grooved longitudinally for the articulation of the lateral covering plates, but at present they are too weathered to verify the former presence of the lateral grooves with certainty. The floor plates overlap each other in a proximal direction, when viewed from above.

Toward the tips of the branches of the ambulacral rays, the floor plates so closely resemble the ordinary interambulacral thecal plates that it seems certain that the floor plates of *Thresherodiscus* are to be regarded merely as specialized thecal plates. Some of the rays appear to intrude even upon the upturned margins of the adjacent plates belonging to the inner band of the peripheral ring. In other words, the ambulacral rays are regarded as epithecal.

From the preceding observations it seems probable that the floor plates of all typical *Agelacrinidae* will be found to be arranged in single rows, and to overlap each other proximally, when viewed from above. This proximal overlapping suggests that the floor plates may be modified thecal plates belonging to the upper face of the theca. This would make the floor plates of the *Agelacrinidae* epithecal, the food grooves extending over the thecal plates themselves, without intermediate flooring. In this respect they are similar to the *Diploporita* among the *Cystidea*, from which they differ in other important particulars.

22. Basal Extensions of Lateral Covering Plates of the Ambulacral Rays

The specimen of *Agelacrinus pileus* described by Miller and Faber exposes in a remarkably clear manner the basal extensions of the lateral covering plates of the ambulacral rays (plate I, Figs. 5A, B, C, D; also plate II, Fig. 4). These extensions project laterally from the bases of the covering plates, where they rest upon the floor plates, toward and beneath the adjacent interambulacral plates. They are best exposed along the anterior, right, and right posterior rays, where they are seen for almost the entire length of the ray, and on both sides of the ray, but some of the basal extensions are seen also in case of the left and left posterior rays. Along that part of the base of each covering plate which serves as its fulcrum, there are two striations (plate I, Fig. 5C), which extend in a direction parallel with the ray, and a moderate distance apart. These striations seem to fit against the inner margin of the narrow lateral groove which is seen on the upper side of the floor plates in certain species. From these bases, of the covering plates, the short basal extensions project outward and downward at rather a strong angle with the major part of the covering plate. The basal extensions are wider on the convex side of the rays, and narrower on the concave side, where there is less room. On the convex side of the rays the basal extensions have a length of about 0.5 mm., and narrow from a width of two-thirds of a millimeter, parallel to the length of the ray, to a width of two-fifths of a millimeter at the truncated tip of the extension. On the concave side of the ray, the basal extensions are much narrower, and terminate more acutely; here they have a length of about 0.4 mm. At the angle of junction of the rays, where also the room is restricted, even the basal extensions on the convex side of the rays are narrow and acute. Apparently two lateral plates occur on each side of each floor plate, in the case of the few floor plates preserved.

In some specimens of *Agelacrinus cincinnatiensis,* the basal extensions of the lateral covering plates are very well exposed. They are shown by specimen 1008-c (plate I, Fig. 6B), in the James Collection, at Chicago University, and also are seen along both sides of the left ray, and on parts of the anterior and left posterior rays of specimen No. 13266-1-c, belonging to the Ameri-

can Museum of Natural History. In the latter specimen numerous basal extensions are present. Here it is noted that the exposed ovate part of the covering plate forms about half the length of the plate. Where it adjoins the margin of the adjacent ambulacral plate, the covering plate is bent downward distinctly but not to any great extent, and then resumes the same curvature as the exposed part of the plate. Immediately beyond the point where the covering plate passes beneath the adjacent interambulacral plate, the covering plate begins to narrow rapidly, and then the sides become approximately parallel, forming the basal extension, which only slightly exceeds one-fourth the total length of the plate. At the interambulacral angles, where there is little room, these basal extensions proceed from the distal side of the covering plates and are directed diagonally (plate I, Fig. 6A) toward the median parts of the interambulacral area.

In *Agelacrinus holbrooki,* No. 1004 of the James Collection in the Walker Museum of Chicago University, several of the basal extensions of the covering plates of one of the rays are sufficiently preserved to indicate that the downward flexure of the covering plates, at their contact with the adjacent parts of the interambulacral plates, takes place at about half the length of the covering plates, and from this point the covering plates narrow rapidly, the terminal fourth forming that part of the basal extension which has approximately parallel sides. The basal extensions seen on part of the anterior ray are very narrow (plate I, Fig. 1E), while those on the left ray (plate I, Fig. 1F, are more like those of *Agelacrinus cincinnatiensis*. These differences may be only local differences along the length of the ray, or may be due to weathering in case of the very narrow basal extensions. Here, again, two covering plates appear to occur on each side of the floor plates.

In *Thresherodiscus* (plate I, Fig. 8), two lateral covering plates also occur on each side of the floor plates. There is no evidence whatever of basal extensions of these coverings plates. In fact, there is no room for the same. In this respect, the covering plates of *Thresherodiscus* resemble those of the *Cystidea.*

Basal extensions of the covering plates are unknown also in *Streptaster* (plate I, Fig. 7B). They probably were absent in the Devonian and Carboniferous *Agelacrinidae*, in which the rays are very narrow (plate I, Fig. 2). It is possible that the presence of basal extensions of the lateral covering plates may prove to be

one of the characteristics serving to distinguish the Ordovician species, usually referred to *Agelacrinus* or *Lepidodiscus*, from the typical Devonian species of these genera. The presence of two lateral covering plates on each side of at least all the larger floor plates has not been established as definitely as desirable, but this also may prove to be a characteristic of the unnamed Ordovician genus as compared with the typical Devonian representatives of *Agelacrinus* and *Lepidodiscus*.

23. Anal Pyramid

The anal pyramid of *Agelacrinus cincinnatiensis* is remarkably well preserved by specimen No. 13266-1-h, belonging to the American Museum of Natural History. Here it consists of an exterior set of eight ovate plates, meeting at the center, and glimpses of three additional plates, belonging to the next inner circle. In specimen No. 13266-b, belonging to the same museum, there are also eight plates belonging to the outer circle of the anal pyramid, and more or less evident indications of eight plates belonging to the inner circle, and alternating with the outer circle. The plates of the inner circle probably were narrower than those of the outer circle, corresponding in this respect to the intercalated plates of the ambulacral cover series. The under side of the larger plates, belonging to the outer series of the anal pyramid, was ribbed longitudinally along the median line, so as to prevent displacement laterally, in this respect also corresponding to the lateral covering plates on the ambulacral rays.

In the closely related *Agelacrinus holbrooki* (plate I, Fig. 1C), there was also an outer series of large ovate plates, and an inner, narrower series, alternating with the former, but the number of each was not determined.

In *Agelacrinus pileus* there also is evidence of larger and smaller sized plates in the anal pyramid, but the outline of the pyramid does not appear to form as rigid a circle, and toward the center these plates overlap more in an imbricating manner so that the margins do not resemble as closely the radii of a circle.

In *Agelacrinus austini* (plate VI, Figs. 1A, C) the anal pyramid consists of an outer circle of 6 ovate triangular plates, with probably an equal number of plates forming an inner circle, but usually hidden more or less by the outer circle.

In *Thresherodiscus* it has been impossible to determine whether the anus is located in the bottom of the depression on the right side of the posterior interambulacral area, or at the top of the immediately adjacent part of the elevation which is present on the distal side of this depression. If the latter was its location, then the anal pyramid consisted of small imbricating plates, not presenting a strongly radial arrangement. If the anus was located at the base of the depression, as more probably was the case, then nothing is known about the anal pyramid.

In *Cystaster granulatus* the anal pyramid is abruptly elevated near the middle of the posterior interambulacral area. It is formed of about 10 somewhat elongated plates, more or less overlapping laterally, so that part are exterior and part more or less interior.

24. Location of the Anus in the Agelacrinidae

Since the *Agelacrinidae* may be regarded as derivatives from a Cystidean type, it may be worth while to emphasize the location of the anus in the posterior interambulacral area, opposite the anterior ray. This is a frequent position of the anus among the *Diploporita*, in *Cystidea*. While a similar position of the anus is described by Bather (*The Echinoderma*, 1900, p. 53) in case of *Echinosphaera aurantium*, from the Ordovician of Europe, the anus in most *Rhombifera* has travelled toward the right, occurring between the right and right posterior branch of the ambulacral system in most *Glyptocystidae*, and between the anterior and right branches in the highly specialized genus *Cystoblastus*, from the Ordovician of Russia.

25. Origin of Ambulacral System of the Agelacrinidae

The fact that the lateral margins of the floor plates of the Ordovician *Agelacrinidae* passes beneath the adjacent margins of the interambulacral plates is opposed to their origin as exothecal plates, as in the *Rhombifera* among the *Cystidea*. The fact that in *Thresherodiscus*, the terminal parts of the branching rays rest upon the margins of ordinary thecal plates, merely depressing their exposed margins a little, suggests the origin of the floor plates as parts of the original thecal covering. The latter structure is

found among the *Diploporita*. Of course, there are no diplopores among the *Agelacrinidae*, and there are no brachioles, so that the *Agelacrinidae* probably originated from an earlier stock, but one in which pseudo-pentagonal symmetry already was present.

As regards the peristomial plates of the *Agelacrinidae*, those of *Thresherodiscus* are the most primitive. In those forms, however, in which the number of peristomial plates was small, as in *Agelacrinus pileus* (plate I, Fig. 5B), the primitive arrangement appears to have been a series of five plates of which the posterior was the largest. The next larger in size were the two plates on the anterior side of the peristomial slit—the plate between the anterior ray and the right ray, and the plate between the anterior and the left ray. The smallest plates of the peristomial series were between the bases of the left and left posterior rays, and between the right and right posterior rays.

While the earlier *Amphoridea* may represent the most primitive types among the *Cystidea*, it is evident that pseudo-pentamerism had developed among the *Cystidea* long before the *Agelacrinidae* deviated from this stock.

The *Edrioasteridae* may have had quite a different origin from the *Agelacrinidae*, since their floor plates are arranged in two series, one on each side of the ray, which alternate along the median line.

26. The Ornamentation of the Surface of the Thecal Plates

The surface of the thecal plates of *Agelacrinus cincinnatiensis* and of *Agelacrinus holbrooki* is essentially smooth. In some of the specimens of *Agelacrinus pileus*, however, the surface is covered by numerous closely arranged very minute pits, seen only under a lens. In specimen No. 13268-1-a, belonging to the American Museum of Natural History, these pits are shown on every exposed surface, including the peristomial plates, the lateral covering plates, the interambulacrals, the plates belonging to the anal pyramid, and the plates forming the inner band of the peripheral ring. Since the small marginal plates of the peripheral ring are not exposed, nothing can be definitely said regarding the latter, but probably the same minute pits are present at least on the larger ones of these marginal plates.

No definite ornamentation was noted on the surface of the plates of *Streptaster*.

In *Thresherodiscus*, there may have been minute granules on the surface of the larger interambulacral plates, but in the present weathered condition of the plates this can not be determined definitely.

I have seen nothing to suggest the presence of distinct and readily recognizable granules on any Ordovician species referred to *Agelacrinus* or *Lepidodiscus*. Such granules as occur on these species appear to belong to species of *Dermatostroma*, covering the surface of the *Agelacrinus* with a very thin, granule-bearing layer (plate I, Fig. 3B; plate III, Figs. 1, 4).

27. The Central or Substomial Cavity of Agelacrinus Pileus

In 1892, Miller and Faber described the lower side of the upper face of a theca of *Agelacrinus pileus* from near the top of the hills at Cincinnati, Ohio. The horizon probably was in the Corryville member of the Maysville. The specimen forms No. 8825 in the Faber Collection in Walker Museum, at Chicago University. In this description (*Journal of Cincinnati Society of Natural History*, vol. xv, p. 85, plate I, Fig. 10; see also plate I, Fig. 5A, and plate II, Fig. 4 of this Bulletin), the following remarks refer to the substomial chamber, as seen from below Explanatory comments are added by the writer in brackets.

> The coverings of the rays (the floor plates, as seen from below) are united near the center of the fossil by a subpentagonal rim, that extends deeper into the visceral cavity than any part of the internal (part of the) rays, and, we believe, extended to the very bottom of the test, and formed the part of the organism that adhered to the foreign object to which these animals attached. Three sides (the anterior sides) of this projecting rim are preserved and shown in the illustration, and the surface is flattened, as if for the purpose of attachment. Within this pentagonal rim there is a pit showing the five subovate mouths of the ambulacral canals, which are also indicated in the illustration.

Miller and Faber did not overestimate the value of this specimen since it is still the best specimen for showing the lower surface of the upper face of the theca. It needs, however, a much fuller description, and such a description is attempted here.

At the center of the theca, as seen from below (plate I, Fig. 5A), there is a substomial chamber or cavity from which the ambulacral rays radiate. The anterior part of the rim of this cavity has a form suggesting a pentagonal outline for the entire rim. This is owing to the fact that this part of the rim appears to be formed by the enlargement and lateral extension of the proximal floor plate of each of the three anterior rays, usually called the left, anterior, and right rays, or rays Nos. 2, 3, and 4. Even if eventually the homology of the rim plates with the proximal floor plates be disproved, the appearance of the rim plates is very well described by this supposed homology. If the specimen be held with the oral side upward, then the proximal floor plate of each of these anterior rays appears to widen rapidly so as to overlap the proximal floor plate of the neighboring ray; at the same time this proximal floor plate curves downward more or less vertically, so as to produce the rim-like effect, as seen from below. The outline of this rim is sufficiently straightened between the median parts of the left and anterior rays, and between the anterior and right rays, to suggest the pentagonal outline. As seen from below, each of the three proximal floor plates arches over the ambulacral groove to which it belongs, leaving an oval opening leading from the median groove in the ambulacral rays into the central substomial cavity.

It must be evident, however, in view of the long transverse peristomial slit, as seen from the exterior view of the specimen, that a corresponding transverse elongation of the substomial chamber must be expected from an interior view, and this is the case. The regularity of the supposed pentagonal outline is considerably disturbed by the acuteness of the angle at which the proximal floor plates of the posterior rays meet those of the lateral rays. This feature is best shown by specimens No. 13266-1-r and x, belonging to the American Museum of Natural History. In both of these specimens, the proximal floor plate of the right posterior ray (No. 5) meets that of the right ray (No. 3) at quite a considerable angle. It is assumed that a similar angulation existed at the angle between the left and left posterior rays. (Plate II, Fig. 3.)

The posterior margin of the substomial chamber, in the Miller and Faber specimen, is formed by a large quadrangular plate, which appears to be merely the lower part of the large quadrangular peristomial plate seen on the posterior side of the peristomial slit as viewed from the exterior. On its inner face, within

the chamber, this quadrangular plate is ridged somewhat like a letter W, the sides of the letter abutting against the thickened inner margins of the adjacent proximal floor plates. Toward the two grooves on the inner side of this posterior quadrangular plate, one on each side of the median ridge, project the strong median ridges of two plates, which, from interior view, have a triangular form, with the broad base against the sutures between the anterior and right proximal floor plates, and between the anterior and left proximal floor plates. These plates probably are merely the interior views of the two rhomboid plates (R and L) seen on the exterior view of peristomial area, and the vertical ridging prevents lateral displacement.

This leaves to be accounted for a peculiar margined depression along the proximal part of the right hand margin of the right posterior ray (No. 5), as viewed from below. This impression involves the two proximal covering plates on the left side of the right posterior ray, where adjoining the right margin of the large posterior peristomial plate, as seen from above. Possibly a duct passed by this path, but its presence could not be verified with confidence. (Plate I, Fig. 5A.)

There is no evidence of the base of this substomial chamber or cavity ever having served as a support of the theca, as suggested by Miller and Faber. It probably was underlaid by the central fleshy aboral face of the specimen. It served chiefly to strengthen the central parts of the upper part of the theca, in the peristomial region.

Moreover, there is no indication of any passage between the mouth and the anus. The gut appears not to have had any special protection apart from the rest of the soft parts of the animal. Moreover, the direction of torsion of the gut is unknown.

28. The Central or Substomial Cavity of Streptaster Septembrachiatus

The lower surface of the upper face of a theca belonging to some species of *Streptaster* is exposed fairly well on a rock fragment found 8 feet below the top of the Elkhorn member, in the upper part of the Richmond, at a small waterfall west of the home of John Miller, a short distance west of the Union road and north of the Eaton pike, about three miles west of Dayton, Ohio.

The original form of the theca was circular, but in its present condition it is somewhat distorted, one of the diameters being 25 mm., while the other, in a transverse direction, is about 20 mm. in length. The longest ray, measuring along the curvature, is 20 mm. in length. All of the rays are so strongly curved that the interambulacral areas are narrow even in the central parts of the theca. The posterior area is about 3 mm. in width. All of the other interambulacral areas are about 2 mm. in width.

At the proximal ends of the ambulacral rays, the floor plates enlarge laterally and also downward (plate I, Fig. 7A; also plate IV, Fig. 2), so as to form a marginal rim enclosing a central cavity, directly beneath the mouth. This part is well exposed but has been weathered so that the details can not be determined excepting for a few plates. The middle plate along the anterior part of the rim is formed by the modified proximal floor plate of the anterior ray. This plate is concave toward the cavity, and its lateral edges overlap the edges of the adjoining marginal plates, on the right and left parts of the anterior rim. Towards its anterior extremity, this plate narrows down to the same width and has the same transverse curvature as the other floor plates. The left part of the anterior margin of the rim, as seen from below is formed by a similar modification of the proximal floor plate of the right ray (No. 4), but the overlapping sides of this plate do not extend as far on the posterior side as on the anterior one. Posterior to the latter is the modified proximal floor plate belonging to the right posterior ray (No. 5).

On the right side of the anterior part of the rim of the substomial cavity, as seen from below, there is a modified proximal floor plate belonging to the left ray (No. 2). Immediately posterior to this should be the modified proximal floor plate belonging to the left posterior ray (No. 1), but the latter is badly weathered, and only the narrow distal termination of this plate can be identified with confidence. The posterior outline of the cavity is formed a mass of material in which it has not been possible to recognize any definite structure.

Immediately in front of the median part of the posterior part of the rim there is a vertical cavity, less than a millimeter in diameter, apparently leading to the oral surface of the theca. This aperture, as seen from below, is bounded on the left by a quadrangular plate filling in most of the lower left hand quarter

of the substomial chamber. On the left side of this quadrangular plate, near the junction between the lateral margins of the proximal floor plates belonging to the right and right posterior rays (Nos. 4 and 5), there is a broad inclined groove.

It has been found impossible to unravel the structure of the peristomial parts of the theca from the view of its under surface, as exposed within the substomial chamber as viewed from below. Apparently this peristomial part consists of a number of small plates instead of a few larger ones, but no definite structure has been recognized. Moreover, no apertures leading from the ambulacral grooves along the median parts of the rays, beneath the modified floor plates, as seen from below, into the substomial chamber, have been detected. Under these circumstances, it is not worth while to speculate regarding the use of the deep depression or aperture at the posterior margin of the substomial chamber, or the purpose of the inclined surface or broad groove on the antero-lateral side of the quadrangular plate filling the left posterior side of the substomial chamber, as seen from below. Possibly the gut twisted in a solar direction, and left the substomial chamber along this inclined surface, but the direction of the gut is unknown in the *Agelacrinidae*.

Description of Several Ordovician Agelacrinidae

29. The Use of the Generic Terms Agelacrinites and Lepidodiscus

Clarke has shown (*New Agelacrinites*, 1901, p. 193) that the type of *Agelacrinites*, the Devonian species *Agelacrinites hamiltonensis*, is characterized by the presence of mosaic interambulacral plates, with irregular polygonal outlines, and a more or less radial sculpture; also by narrow rays, and a well developed peripheral ring consisting of an inner band of large plates and a marginal zone of small plates.

From typical *Agelacrinites*, the Ordovician species formerly referred to *Agelacrinus*, merely a different spelling to the same generic term, differ in the presence of imbricating interambulacral plates, and wider rays. It should be noted also that the floor plates of *Agelacrinites beecheri* are narrower, and evidently support only one lateral covering plate on each side, instead of being

broader and supporting two covering plates on each side, as in the Ordovician species referred to *Agelacrinus*.

In *Lepidodiscus*, as defined by Clarke, all of the thecal plates are squamose and imbricating, and in one species, *Lepidodiscus alleganius*, these plates are present even on the aboral surface. The chief feature is the essential absence of a distinct peripheral ring with an inner band of larger plates and an outer zone of much smaller plates. As in other Devonian *Agelacrinidae*, the rays are narrow.

From typical *Lepidodiscus*, the Ordovician species recently referred by some authors to *Lepidodiscus*, in preference to *Agelacrinus*, are distinguished by the presence of the distinct peripheral band, and by broader rays.

From this it will appear that neither *Agelacrinus* nor *Lepidodiscus* are suitable terms for the Ordovician species hitherto referred to these genera, as pointed out by Clarke in 1901, and it will be necessary to propose a new generic term for the latter. In the present paper the term *Agelacrinus* is retained temporarily for the Ordovician species formerly described under that name, as being at least more noncommittal than *Lepidodiscus*, since the term *Agelacrinus* was long used in a very broad sense.

30. **Thresherodiscus ramosa,** Gen. et sp. nov.

(*Plate I, Fig. 8; Plate III, Fig. 3*)

An interesting *Edrioasteroid*, with branching ambulacral rays, a feature hitherto unknown in this group of *Echinoderma*, was found by the writer, during the summer of 1912, on Goat Island, northeast of the village of Little Current, the chief town on Manitoulin Island, Lake Huron, Ontario. The exact locality is at the point where the railroad from LaCloche Island strikes the northeastern edge of Goat Island. Here *Carabocrinus vancortlandi* is common 7 feet above the lake level. In the overlying strata, 4 feet thick, *Plectambonites curdsvillensis* occurs at various levels. The *Thresherodiscus* was found at a horizon belonging stratigraphically 18 feet above the lowest strata exposed at the edge of the lake. Here it was associated with *Cleiocrinus regius, Reteocrinus alveolatus, Cyclocystoides halli,* and a species of *Lichenocrinus*. Between 24 and 28 feet above the lowest horizon, *Glyptocrinus ramulosus* was represented by abundant remains of the

long, large column, and occasional parts of the basal portion of the cup. The southern exposures on Cloche Island evidently are of Black River age, and therefore these most northern exposures on Goat Island probably belong low in the Trenton section. They are correlated provisionally with the Kirkfield and Hull horizons of Ontario and the Curdsville bed in central Kentucky. The following is a description of the *Thresherodiscus ramosa*, here found.

Genotype, Thresherodiscus ramosa

The generic name is given in honor of Mr. and Mrs. J. B. Thresher, of Dayton, Ohio, in appreciation of the many years of encouragement given the writer in his efforts at scientific investigation. The type forms No. 8446 in the collections of the Canadian Geological Survey, in the Victoria Memorial Museum at Ottawa, Canada.

Theca discoid, 16 mm. in diameter. Upper surface gently convex, excepting at the sides where the slope becomes steep. Vertical height between 4 and 5 mm. Lower surface not exposed, apparently resting upon the surface of some bryozoan. Animal probably not permanently sessile, but capable of changing its location.

Mouth central. From this mouth three ambulacral rays diverge—an anterior, a right, and a left primary ray. The right and left primary rays form an angle of 150 degrees with each other; the anterior ray is directed sufficiently far to the left to make an angle of about 90 degrees with the left primary ray. All these primary rays bifurcate dichotomously at least twice, the first of these bifurcations taking place about 2 mm. from the center of the oral area.

Regarding the trimerous radial structure as primitive among the *Echinoderma*, and the more obvious pentamerism of this group as secondary, the correlation of the ambulacral rays of *Thresherodiscus* (Fig. 1) with those of other *Agelacrinidae* becomes obvious. Designating the left posterior ray of the ordinary *Agelacrinidae* as No. 1, and the other rays in succession in dextral order as 2, 3, 4, and 5, the last number is given to the right posterior ray. Using the same numbers for the rays of *Thresherodiscus*, the anterior primary ray (*A*) evidently corresponds to No. 3. The first branches of the right primary ray

(*R*) correspond to rays 4 and 5, and the first branches of the left primary ray (*L*) correspond to rays 1 and 2, using these numbers in dextral order, as heretofore. In the following lines the terms left posterior, left anterior, anterior, right anterior, and right posterior will be used to express the homologies of the rays here indicated.

The first dichotomous branching of the anterior ray takes place 2 mm. from the center of the oral area. The left and right branches of the anterior ray bifurcate again at distances of 3.5 and 4 mm. respectively from the first fork, the secondary branches (*s*) not exceeding 2.5 mm. in length.

Rays Nos. 1, 2, 4, and 5 bifurcate dichotomously (*a*, *p*) at distances of 2.3 to 2.6 mm. from their origin at the ends of the left and right primary rays, most of the branches varying in length

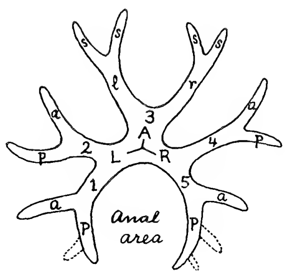


Fig. 1. Diagram of ray system of *Thresherodiscus ramosa*. *A*, *L*, *R*, anterior, left, and right primary rays. *1*, *2*, *3*, *4*, *5*, left posterior, left, anterior, right, and right posterior rays; *l*, *r*, left and right branches of anterior ray; *a*, *p*, anterior and posterior branches of rays *1*, *2*, *4*, and *5*.

from 3 to nearly 4 mm. The posterior interambulacral area contains the anus, on the side nearest the right posterior ray, as in other species of the *Agelacrinidae*. This posterior interambulacral area is of oval form, 4.5 mm. in width and nearly 7 mm. in length, following the curvature of the theca. The posterior branch of the right posterior ray, bordering the right posterior outline of the anal interambulacral area, appears to branch a second and third time, at distances of 2 and 4.5 mm. from the first fork of this ray, and similar forking may take place on the left posterior side of this anal interambulacral area, but the evidence for this is not perfectly clear.

Floor plates (plate I, Fig. 8, f l), forming the lower or thecal side of the ambulacral rays, large and extending the entire width of the ray. Their general outline is quadrangular. The lateral thirds of the width of each floor plate are flat, but the median third is distinctly furrowed by the ambulacral groove which is deeper toward the mouth but becomes quite shallow near the terminal branches. Following the floor plates from the mouth toward the extremities of the branches, the distal end of one plate is overlapped slightly by the proximal end of the next succeeding plate.

In the case of the anterior ray, the floor of the primary part appears to be formed by two plates, poorly exposed. The floor plates of the first branches are clearly exposed—three forming the floor of the right branch, and two forming the floor of the left branch. At the end of the left branch, a floor plate on the left overlaps a floor plate on the right, thus starting the secondary branches. The floor plates of the secondary branches number at least three or four, but at the tips of the branches the outlines of the floor plates are not clearly exposed, nor are they clearly differentiated from the adjacent marginal plates.

The floor plates of the left primary ray are not exposed but the length of this part is sufficient to admit of two plates. The primary part of the branch here designated as ray No. 2 appears to rest upon two floor plates. The anterior branch of ray No. 2 rests on at least four floor plates. The posterior branch of this ray rests on three distinctly grooved floor plates, beyond which are two or three thecal plates on which the grooving is faint. The anterior branch of ray No. 4 is supported on four floor plates of which the last is only moderately grooved; beyond this are about three thecal plates, belonging to the laterally elongated marginal series, which also show faint grooving. The floor plates of the posterior branch of this ray are not exposed.

None of the floor plates of the right primary ray, or of any of its branches, are exposed.

The entire width of the floor plates is covered by the ambulacral rays. The covering plates consist of two conspicuous lateral series (plate I, Fig. 8, c, c)—one series on each side of the ray, or of its various branches—and of numerous much less conspicuous central covering plates, to a large extent also arranged in two series, along the median part of the rays. The lateral covering plates rest upon the extreme sides of the floor plates. The lat-

eral edges of these lateral covering plates overlap each other, the distal side of one plate being covered by the proximal side of the next succeeding plate. The general form of the lateral covering plates is elongate pentagonal, the tips alternating with the central covering plates. About six lateral covering plates occupy a length of 2 mm. This suggests the presence of at least two lateral covering plates along the side of each floor plate, probably decreasing to one on each floor plate as the smaller extremities of the last branches are reached.

In one respect the structure of the rays of *Thresherodiscus* differs strongly from that of *Agelacrinus cincinnatiensis*, *A. pileus*, *A. holbrooki*, and probably also of other Ordovician species usually referred to *Agelacrinus* or *Lepidodiscus*. There is no known prolongation of the lateral covering plates extending laterally beneath the adjacent interambulacral plates.

The central covering plates of the ambulacral rays, or rather those parts of these plates which are visible, are very small and the definite determination of their arrangement is difficult. Along one part of one ray these central covering plates are arranged in two series, alternating both with each other and also with the tips of the lateral covering plates. However, there are other parts of the specimen in which the central plates appear to be more numerous than the lateral ones, and in which the arrangement, in consequence, appears less regular.

The interambulacral plates differ conspicuously in size. Of these, the central plates (plate I, Fig. 8, ia) are much larger, distinctly squamose, and imbricating, the distal end of one being overlapped by the proximal end of the next. Owing to the rather numerous branches of the rays, the primary interambulacral areas are so much divided and the individual parts so narrow that the large squamose plates along the center either form an approximately straight row, or a more or less strongly zigzagging series, alternation being always conspicuous at the distal end of the series, where the large, central interambulacral plates merge into the numerous laterally elongated plates that belong to the inner band of the peripheral ring. The nearest approach to a single straight series of large plates is found in the interambulacral space starting at the point of divergence of the proximal parts of rays Nos. 1 and 2, and in that which starts in the angle between rays Nos. 3 and 4. The approximately straight part of these series is

confined to only about four plates, the more distant interambulacral plates alternating distinctly in all cases.

Surrounding the central series (plate I, Fig. 8, ia) of large squamose, imbricating interambulacral plates, in each division of the interambulacral areas, there is a continuous series of much smaller bordering plates (plate I, Fig. 8, b), arranged with their longer axes more or less perpendicular to the adjoining branches of the ambulacral arms. Toward the central part of the theca, these bordering plates usually vary from one-third to one-half of a millimeter in length, while the number along the side of the ambulacral rays is about equal to that of the adjacent lateral coverings plates, or is moderately greater. Usually there is only a single series of bordering plates between the various branches of the ambulacral rays and the conspicuous plates along the center of the included parts of the interambulacral areas. The most conspicuous deviation from this arrangement in a single series is found in the anal interambulacral area, which is distinctly wider than any of the other areas, and in which the additional space, on both sides of the central series of large plates, is occupied by additional, but more or less irregularly arranged, bordering plates. These bordering plates may be traced almost to the extreme ends of the smallest branches of the ambulacral rays, and form the readiest guide to the course of the various branches of the rays, when the covering plates are absent, since the floor plates here so closely resemble the adjacent thecal plates.

The anus is situated in the posterior interambulacral area. This is the area in which the bordering plates, between the large squamose central plates and the adjoining branches of the ambulacral rays are so numerous. The area is rounded oval in form. The exact location of the anus is on the right side of the series of large central plates, near mid-length of the area. Apparently it is at the base of a deep depression but this may be due only to muscular contraction on the death of the animal. On the distal side of the anus the plates are of small size, gradually merging into the laterally elongate plates belonging to the upper rows of the marginal series. If the anus was protected by a pyramid of small plates, this pyramid is concealed at present at the base of the anal depression.

The mouth was located centrally. The peristomial plates are not preserved in the only specimen known. The lateral covering

plates of the left primary ambulacral ray may be traced on the anterior side, in a proximal direction, as far as the first lateral covering plate at the proximal end of the anterior ray, while on the posterior side of this left primary ray they may be traced to a point on the posterior side of the mouth, opposite the median line of the anterior ray. These lateral covering plates show no enlargement along the oral slit, so that it is regarded as very probable that the peristomial plates did not differ conspicuously in size from the adjoining lateral covering plates, as is the case in *Agelacrinus pileus*, and to some extent also in *A. cincinnatiensis*, and probably also in other Ordovician species referred to *Agelacrinus* or *Lepidodiscus*.

Beyond the extremities of the remote branches of the ambulacral rays, there is a marginal or peripheral zone of imbricating squamose plates resembling those of the inner band of the peripheral ring of other *Agelacrinidae*. Only the proximal ends of these plates are well exposed, but these are sufficiently extended laterally to indicate that their general form is short but broad. In a proximal direction these marginal plates are successively larger in size, merging gradually into the series of large central interambulacral plates. In a distal direction, on the posterior border, the marginal plates of the peripheral ring become successively shorter and more numerous, and resemble the marginal plates of *Lepidodiscus cincinnatiensis*, as illustrated by Hall, in Figure 7 on plate 6, of the *Twenty-fourth Annual Report of the New York State Museum*. They are ornamented by short parallel vertical ridges or elongated granules. On the anterior border, there is a series of narrow, but elongate imbricating plates, resembling the narrow imbricating scales of the cup at the base of an acorn, or the plates at the base of the margin of *Streptaster vorticellatus*, as illustrated by Hall in Figure 12 of the plate cited above. There is no means, at present, of accounting for these differences in appearance of the smaller plates along different parts of the border. Of the larger plates, forming the inner band of the peripheral ring, there appear to be about six rows, counting in a diagonal direction, beneath which, along the anterior margin, there are three or four rows of the smaller narrow plates. Along the posterior border, there are five or six lower rows of smaller plates, but these are laterally elongated as in the case of the overlying rows of larger sized peripheral plates.

No surface ornamentation was detected upon any of the larger

interambulacral plates. There is a tendency toward a ridge parallel to the longer diameter of the plate in case of the bordering plates, along the sides of the rays. There is no evidence of pores or of a madreporite.

Thresherodiscus differs from all other *Edrioasteroidea*, hitherto described, in the presence of branched ambulacral rays, and in the very pronounced trimerous origin of these rays. The strong differentiation between a central series of large squamose imbricating interambulacral plates and the smaller bordering interambulacral plates is noteworthy.

The presence of a single row of large floor plates is an interesting feature, but is known also in *Agelacrinus cincinnatiensis, A. holbrooki, A. pileus, A. faberi,* and *A. austini.*

It is evident that *Thresherodiscus* finds its nearest relatives among the *Agelacrinidae,* but it probably had quite a different origin from the Ordovician species usually referred to *Agelacrinus.*

31. **Agelacrinus vetustus,** sp. nov.

(Plate III, Fig. 1)

For ten years I have had in my possession a specimen of *Agelacrinus* which is of interest chiefly because it was found in the Greendale or richly fossiliferous member of the Cynthiana formation, on the south side of the Kentucky River, at Clays Ferry, 14 miles southeast of Lexington, Kentucky, opposite the southeastern corner of Fayette County. It occurred in the fossiliferous strata between 38 and 69 feet above a massive limestone layer, near a road side watering trough. The specimen is attached to a pedicel valve of *Rafinesquina,* and apparently is covered by the thin, densely papillate stroma of some *Dermatostroma,* which obscures the outlines of all of the thecal plates excepting those belonging to the ambulacral series, and even here tubercles are found on the outer, exposed faces of the lateral covering plates. This papillate stroma does not extend from the theca of the *Agelacrinus* on to the surface of the *Rafinesquina,* upon which it rests. In fact, for some reason this stroma does not actually reach the extreme margin of the theca but is separated from the latter by a very narrow space along which the vertical ridges belonging to the outermost rows of very small marginal plates are exposed. Ridges of a similar sort are illustrated by Hall. *Twenty-fourth Report of the New York*

State Museum, by figure 12 on plate 6; which is reprinted as figure 4 on plate 6 of this Bulletin. The papillae on this stroma are largest nearer the margin of the theca, becoming smaller in the interambulacral spaces and on the lower parts of the covering plates. The ambulacra, mouth, and anal passage apparently were not obstructed, or at least were only partially obstructed.

The anus is located in the center of the posterior interambulacral area, the papillate stroma constricting the passage and rising slightly around it. This suggests that the *Dermatostroma* spread over the theca during the life of the animal. The peristomial plates consist of a broad posterior plate and of two diagonally rhomboid anterior plates, as in *Agelacrinus pileus*. The upper margin of the posterior plate, as viewed from above, is broadly V-shaped and an angulation probably extended along its median line.

As far as may be determined, through the covering papillate stroma, the upper plates of the marginal series and the interambulacral plates corresponded in size and form to those of *Agelacrinus pileus*, and it is to this species that the Clays Ferry *Agelacrinus* is most closely related.

Theca very depressed convex, circular in outline, 12 mm. in diameter and about 2 mm. in height at the junction of the rays. Rays moderately curved, four sinistral and one dextral. Four of the interambulacral areas at present are depressed but this depression evidently took place after the death of the animal. The anterior rays meet the marginal rim at angles varying from 30 to 50 degrees. The left posterior ray meets the rim at an angle of about 70 degrees and the right posterior ray forms an angle of about 30 degrees. The tips of none of the rays are extended parallel to the peripheral ring, as in *Agelacrinus cincinnatiensis*, and as also to some extent in *A. pileus*.

The most characteristic feature of this Clays Ferry species is presented by the lateral covering plates. The ambulacral rays apparently were somewhat elevated as in *A. pileus*. The lateral covering plates on opposite sides of the ray alternate with each other as in other species of this group. Along the upper surface of the rays, however, they appear like a series of short ridges arranged transversely to the length of the rays. In their narrowness and length these lateral covering plates differ conspicuously from those of *Agelacrinus pileus*, in which these plates are

shorter and broader, and terminate abruptly in acute points, when viewed from above. On the anterior and left anterior rays, there are about twelve or thirteen pairs of lateral covering plates; on the right posterior ray there are about eleven pairs; on the two remaining rays, there are about ten pairs.

The papillae of the *Dermatostroma* number about six or seven in the length of 1 mm. in the interambulacral areas, and four or five in the same length at some points along the margin.

The animal probably was capable of shifting its position from place to place, and, in consequence, the *Dermatostroma* did not extend from the theca of the *Agelacrinus* over on to the shell of the *Rafinesquina*.

The small curvature of the rays is a primitive character. This character should be sufficient to distinguish *Agelacrinus vetustus* from *A. pileus*, in which the distal end of the rays turns sufficiently to become parallel to the peripheral band for a short distance. An even more primitive condition is shown by the Trenton *Agelacrinus billingsi*, Chapman, in which the rays are sharp and quite straight, the distal end abutting against the peripheral ring.

Agelacrinus pileus is listed by Nickles from the Corryville member of the Maysville but I have seen specimens on the same slab with *Plectorthis plicatella*, thus suggesting an earlier age for some of the specimens.

Agelacrinus vetustus is merely another example of the rather numerous cases in which typical Maysville species are represented in the Cynthiana formation by closely similar forms.

32. **Agelacrinus faberi,** Miller

(*Plate I, Figs. 3 A, B, C; Plate III, Fig. 4*)

(*Journal, Cincinnati Society of Natural History, vol. XVII, p. 156, Plate 8, Figs. 24, 25, 1894*)

This species was found by C. L. Faber "in the extreme upper part of the Hudson River (Cincinnati) Group, about half way be-between Osgood and Versailles, Indiana." The type, at present, forms No. 8821 in Walker Museum, at Chicago University. It probably belongs to the Whitewater division of the Richmond, immediately above the typical Saluda.

The type is too poorly preserved to merit description. It undoubtedly would not have been described had it not been for

the presence of numerous tubercles supposed to belong to the original ornamentation of the plates. In the original description it is stated that "the surface of all the plates is densely and beautifully tuberculated. This species is distinguished from all others, in rocks of the same age, by the tuberculated plates." As a matter of fact, all plates are not densely and beautifully tuberculated, and it is doubtful whether the tuberculation belongs to the plates, as an organic part of the same.

If I have correctly interpreted the orientation of this specimen, then the transverse slit along the oral parts is parallel to a line drawn diagonally across the brachial valve of the *Hebertella alveolata*, upon which the specimen rests; this line is to be drawn from the right hand end of the hinge line to the left antero-lateral angle of the valve. The anterior parts of the theca lie nearer the anterior margin of the valve. The broad, peristomial plate, posterior to this slit, and the right one of the two plates immediately anterior to this slit appear to be preserved. There appear to be traces of the two posterior rays enclosing the supposed anal interambulacral area, but most of the plates within this area are missing and those present are more or less displaced and tilted at various angles, making their definite interpretation impossible.

The right anterior, and anterior rays are strongly curved in a sinistral direction, but only the terminal parts are even fairly preserved. At the proximal end of the anterior ray, apparently one or two floor plates are exposed. Several floor plates belonging to the left anterior ray also appear present. They form a single series, are depressed along the center, are about as long as wide, and overlap each other in a proximal direction. Possibly the floor plates described by Meek (*Ohio Palentology*, vol. I, p. 55) belong to this Richmond species. Nearly all of the plates belonging to the left posterior interambulacral area of *Agelacrinus faberi* are missing.

The plates of the interambulacral areas are of medium size, but the first circle of plates immediately exterior to the terminations of the ambulacral arms, belonging to the inner band of the peripheral ring, consists of large transverse plates, varying between 3 and 4 mm. in width. Exterior to these are about two circles of plates, nearer 2 mm. in width, between which and the margin there are two, three, or four successively smaller plates. In the original description it is stated that this species is "distinguished

from *Agelacrinus cincinnatiensis* and *A. pileus* by the absence of the great number of small plates that form the periphery in those species, and also by having the larger plates of the body, in the rim, that surrounds the ends of the rays." However, the plates forming the inner band of the peripheral ring do not appear unusually large to me, and the smaller marginal plates seem few in number, apparently merely because most of them have fallen off.

As already mentioned, it is very doubtful whether the tuberculation can be considered a part of the original ornamentation of the thecal plates. The tubercles resemble very much those of *Dermatostroma papillata*, James, although of smaller size and more closely approximated. In *Dermatostroma papillata*, the tubercles number about three or three and a half in a length of 1 mm., while those on the plates of *Agelacrinus faberi* number about five in the same length. The reason for interpreting these tubercles as due to the presence of *Dermatostroma* are the following. The tubercles on the plates are arranged more or less in rows. On the larger plates, along the posterior margin, these rows appear in several cases to pass from plate to plate, and are not interrupted at the margin of the individual plates. Where the imbricating plates are separated from one another, these tubercles, in a number of cases, are seen to be present also between the dislocated plates, where evidently they would interfere with the close fitting together of the plates during the life of the animal. Moreover, along the left anterior margin, the tubercles hide the limits of even the larger plates, as though a thin tuberculous stroma had passed over these plates, and also over the terminal parts of the anterior ray, on to the adjacent parts of the interambulacral area. Finally, on some plates, apparently as well preserved at the rest, no tubercles are present or these are only faintly represented, as though in initial stages of growth, while adjacent plates of the same series have tubercles. Until other specimens at the same horizon, are found, in which the tubercles can be demonstrated as original parts of the surface ornamentation, I shall regard this feature of the type specimen as due to the presence of some *Dermatostroma*.

The only surface ornamentation with which I am familiar among Ordovician species usually referred to *Agelacrinus* or *Lepidodiscus* is that of *Agelacrinus pileus*, and this appears minutely and irregularly pitted, rather than tuberculated.

Under these circumstances, *Agelacrinus faberi* can not, as yet,

be considered a well established species. It has already been noted that the specimen described by Meek in the *Paleontology of Ohio*, vol. 1, p. 55, in 1873, from the upper part of the Richmond group, at Richmond, Indiana, probably belonged to the same species. Its nearest relative appears to be *Agelacrinus pileus*.

33. **Agelacrinus austini,** sp. nov.

(*Plate VI, Figs. 1A,B,C.*)

This species is characterized chiefly by its small size. The largest specimen at hand does not exceed 10 mm. in diameter. The upper surface is of very moderate convexity. In a specimen 8.5 mm. in diameter (fig. 1A on plate VI), that part of the ray which is parallel to the inner band of the peripheral ring is about as long as the straight, proximal part, radiating directly from the oral center. In a specimen 7.5 mm. in diameter (fig. 1C, on pl. VI), the rays are more gently curved and meet the peripheral ring at an acute angle without being strictly parallel to it for any distance. In a still smaller specimen, 6.5 mm. in diameter on the same support as the original of figure 1C, the left posterior ray, No. 1, is almost straight, and the remainder are but very moderately curved, meeting the peripheral ring at rather obtuse angles, compared with the rays of larger sized specimens. The exposed part of the lateral covering plates is ovate-triangular in form, and the spaces between adjacent plates are occupied in each case by one of the central or median series of covering plates, of which a relatively greater length frequently is exposed than in the case of any other known species. Commensurate with the small size of the specimens, the number of the squamose interambulacral plates is rather small. The anal pyramid consists of an outer circle of 6 ovate-triangular plates, between which can be seen glimpses of an inner circle, probably of about the same number. The inner band of the peripheral ring consists of one circle of large plates, considerably extended laterally. Above this is a circle of smaller plates graduating into the interambulacral series; and below is a third series graduating into the successively smaller plates forming the outer or marginal part of the peripheral ring.

The conspicuousness of the larger plates of the inner band of the peripheral ring of Ordovician species referred to *Agelacrinus*

usually is not a specific characteristic but is merely an indication of the degree to which these plates are exposed, as the result of being drawn apart in a radial direction by means of tension. In specimens of *Agelacrinus pileus*, resting upon an inclined surface, for example in figure 1 on plate II, this tension usually is along the upper margin of the sloping specimen. In specimens resting upon a flat surface, with the outer margin of the peripheral ring widely extended, the plates forming the inner band of the peripheral ring often are well exposed along the entire circumference. In the case of *Agelacrinus austini* also there is considerable variation in the conspicuousness of the plates forming the inner band, and no features are noticed in this connection which may be regarded as specific. As in other species, the marginal plates are successively smaller, those forming the outer row being very narrow and elongated in a vertical direction.

Peristomial plates not clearly defined in the specimens at hand but believed to include plates corresponding to L, R, and P, in figure 5B, on plate I of this paper.

Inferior aspect of upper part of theca (fig. 1B, on pl. 6) as in figure 3 on plate II, which is supposed to be the inferior aspect of a specimen of *Agelacrinus pileus*. Floor plates of rays 4 and 3 distinctly defined along the entire length of the rays. All of the floor plates of ray 1 are present; of these the proximal floor plate is considerably displaced, and the rest are slightly disjointed. They are strongly arched, as viewed from below, evidently consist of a single series of plates along each ray, and permit no glimpse of the basal extensions of the lateral covering plates. The proximal floor plate of ray No. 3 overlaps the adjacent edges of rays No. 4 and 2.

Specimens found in the upper part of the Whitewater division of the Richmond, four and a half miles northwest of Wilmington, Ohio, at the *Drepanella richardsoni* horizon, by Dr. George M. Austin, of Wilmington, and belonging to his collection.

34. **Agelacrinus holbrooki,** James

(*Plate I, Figs. 1 A–F: Plate IV, Fig. 1*)

(*Paleontologist, No. 1, p. 2, 1878,*

Journal, Cincinnati Society of Natural History, vol. X, p. 25, Figs. A, B, 1887)

A specimen of *Agelacrinus holbrooki*, from the James collection, is in the Walker Museum at Chicago University, and is numbered 1004. I strongly suspect that this specimen is the type, for the following reasons. The left anterior ray is preserved almost entire. The proximal part of the left posterior ray for a distance of about 12 mm. from the probable center of the oral parts is missing. Of the right posterior ray only the terminal U-shaped part is present; the remainder, from the oral parts to that part which is about as far distant as the more remote part of the anal opening, is missing. There is no trace of the right anterior ray, of the interambulacral areas above or below this ray, or of the oral parts. Only the distal, U-shaped part of the anterior ray is present, but the proximal part of the left anterior interambulacral area seems sufficiently preserved to indicate with some exactness the direction of the proximal part of the anterior ray. If, without giving any attention to the orientation of the rays, the specimen be turned so as to place at the top the exposed part of the fragment of pedicel valve of *Rafinesquina alternata*, upon which the specimen rests, then an outline similar to that of the published figure of the type is presented; that part of the margin of the theca which is at the top curves outward in a concave manner, and that part which is at the bottom curves downward and inward, so as not to be exposed. In that position, however, the orientation of the rays is different from that presented in the published figure of the type. I strongly suspect that the artist took considerable liberties with the specimen, first drawing the general outlines and general form of the specimen correctly, and then twisting the specimen through an angle of about 60 degrees to the right before putting in the details of the rays and interambulacral areas.

One of the most characteristic features of *Agelacrinus holbrooki* is the strong convexity of the upper surface of the theca. The greatest diameter of the specimen is 30 mm., and this is the diameter also in a transverse direction. The height is about 16 mm., the theca rising rather abruptly from the margin, thus giving it the sub-globose surface noted by James. Ambulacral rays rising but

slightly above the general convexity of the theca. At their distal ends they extend parallel to the marginal series of plates only for short distances; the two posterior rays, for about 5 or 6 mm.; the left anterior ray, for 3 or 4 mm.; and the anterior ray, for about 8 or 9 mm. Then the different rays curve strongly upward and around, so that the tips, if extended in a straight line, would strike the proximal part of the rays at points nearer than the oral center of the theca. The length of these recurved tips of the rays varies between 4 and 5 mm. The lateral covering plates are elongate triangular, the spaces between the tips being occupied by smaller and more centrally located covering plates. Covering plates belonging to the central series crowd in locally between the lateral plates, especially along the outer or convex outlines of the rays, at the points of greatest curvature. Along the inner or concave curve of the anterior ray, of the specimen here described, the covering plates have been weathered away, exposing the floor-plates of this ray. These floor plates are quadrangular in form, are 1.5 mm. in length, and 2 mm. in width. Five consecutive floor plates are visible. A distinctly defined groove, half a millimeter in width, extends along the median line of the floor plates. The lateral covering plates rest upon the sides of the floor plates. In the case of three of the floor plates, there appears to be a shallow longitudinal groove along that side of the floor plate which is on the inner or concave side of the curvature of the ray. It is probable that this lateral groove extends along the entire length of the ray, and that it occurs also on the opposite side of the ray. From the basal part of the lateral covering plates along the convex side of this ray, there extends a short projection, about two-thirds of a millimeter in length, which projects outward and downward at a low angle, but sufficient to pass beneath the nearest interambulacral plates. These basal projections are narrower than the width of the lateral plates and probably offered attachment to the muscles drawing the basal projections downward and the tips of the lateral covering plates, on opposite sides of the ambulacra, away from each other.

The interambulacral plates are arranged in rows crossing each other diagonally. Those in the left posterior interambulacral area are best preserved. Their general form is more or less rhombic, with sufficient of the top and bottom angles truncated in some plates to suggest an hexagonal outline. Along the margins of the interambulacral areas, the plates are smaller and their outlines

more irregular. At their margins the scales are closely appressed, the proximal parts of each scale overlapping the distal outlines of the next scale, in a direction toward the central part of the theca, although the amount of overlap is small. Strictly defined, the interambulacral plates are imbricating, and not mosaic, at contact.

Only the lower part of the anal region is preserved in the specimen. Several of the triangular plates of the anal pyramid are present. The adjoining plates are small, forming a very narrow band on the lower left side of the pyramid, widening on the lower right side toward the termination of the right posterior ray. This part is well figured by Clarke, in his paper on *New Agelacrinites*, in Bulletin 49, New York State Museum, p. 189, Fig. 2, 1901, (reprinted as Fig. 1c on plate VI of this BULLETIN) illustrating specimen No. 40744, in the United States National Museum, which is labelled as coming from Morrow, Ohio. This probably was the locality from which the type of the species was obtained, the collector, Professor Holbrook, having lived at Lebanon, Ohio. Morrow was the type locality also of *Agelacrinus warrenensis*. It was a well known collecting ground.

The marginal parts of the type specimen, as here identified, below the distal parts of the ambulacral rays, consist of two series of plates, grading into each other. Those immediately below the rays are of small vertical height but of considerable lateral extent. They are arranged in three or four rows, the plates becoming successively smaller, and grading into about three rows of much smaller plates, resembling in form the overlapping scales of an acorn cup.

Agelacrinus holbrooki is listed by Nickles from the Corryville division of the Maysville.

35. **Agelacrinus warrenensis,** James

(*Plate I, Figs. 4 A, B*)

(*Paleontologist, No. 7, p. 58, Plate II, Figs. 3, 3a, 1883*)

The following is the description presented by James:

Body circular, varying in diameter from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch or more. Attached to the convex valves of Strophomena (known at present as Rafinesquina), and, probably, other foreign substances; the under side concave, or otherwise, conforming to the surface grown upon. Disc composed of squamiform plates, overlapping inward from the periphery;

the plates of the outer margin very small and arranged in a narrow rim all around, the larger plates taking their place abruptly. About one line or a little more inward the surface becomes suddenly depressed, causing quite a sharp outward ridge, in most cases all round, by the projecting edges of the plates; and then rises, gently at first, but abruptly nearer and to the center, forming a somewhat prominent dome. The rays or arms nearly hidden by the imbricating plates in all the specimens examined; but occasionally some of the arms are partly but indistinctly shown, as is the case in the figured specimen. The ovarian aperture (anus) is hidden, probably, in the same way, it not being shown in any one of the specimens. All but one of the ten examples used for this description show the above specified characters, and that one is, evidently in an abnormal condition by lateral pressure.

Found by Dr. T. D. Dyche, of Lebanon, Warren County, O., in beds of the Cincinnati Group, equivalent to the tops of the hills at Cincinnati. The type specimens are in Dr. Dyche's fine collection.

According to Dr. Dyche, the type locality was a short distance up a small branch entering Second Creek at the first bridge east of Morrow, in Warren County, Ohio. The types were associated with *Dalmanella multisecta*, in the same rock. Two of the type specimens were presented to me by Dr. Dyche.

The presence of *Dalmanella multisecta* suggests the Fairmount member of the Maysville, since nothing lower than this member is shown along Second Creek.

At the same locality, east of Morrow, I have collected *Phyllo-porina clathrata*, *Plectorthis equivalvis-latior*, *Plectorthis equivalvis-pervagata*, *Playtstrophia* of the *ponderosa* type but rare, *Rafines-quina squamula*, *Zygopira cincinnatiensis* large, *Protowarthia morrowensis* (= *cancellata*), *Dalmanites carleyi*, and an *Isotelus* with a genal spine three-fourths of an inch long. About a mile east of Morrow, *Rafinesquina ponderosa*, characterizing the Belle-vue horizon, is common. At a higher level the Corryville comes in.

The impression produced by the types of *Agelacrinus warrensis* is that of a suite of young individuals of *Agelacrinus cincin-natiensis*. As far as the sudden depression within the peripheral ring and the dome-like elevation at the center are concerned, these are not diagnostic features at all, but merely indications of rapid decay of the underlying viscera after the death of the animal, the inner band of the peripheral ring and the central or substomial chamber being most rigid and retaining their form best. More-over, the ambulacral rays and the anus are hidden only in the

sense that they can not be located readily in specimens which have their thecal plates more or less disarranged, and this is true of the types of *Agelacrinus warrenensis*.

An excellent young specimen of *Agelacrinus cincinnatiensis* is preserved in the American Museum of Natural History, and forms No. 1194–IV of that collection. It is 10 mm. in diameter, rests upon a *Rafinesquina*, and displays five rays, one of them dextral. The tips of the rays already are sufficiently curved to become parallel to the peripheral band. An examination of this specimen will readily illustrate how difficult it would be to recognize the rays if the thecal plates were only moderately disarranged while the disarrangement of the thecal plates of the types of *Agelacrinus warrenensis* was fairly considerable.

36. **Streptaster**, Hall, generic characteristics

The term *Streptaster* was proposed by Hall in 1872 as a subgeneric term under *Agelacrinus*, and was founded on *Streptaster vorticellatus*, Hall, at that time the only species known. Later, in 1878, a closely related species, *Streptaster septembrachiatus*, was described by Miller and Dyer. Since both species had all of the rays sinistral, this appeared to be the most striking characteristic of the genus. In the present paper, however, a species with the right posterior ray turned in a dextral direction is described, so that this feature looses in diagnostic value. .

The chief characteristics of *Streptaster*, as far as known at present are the following.

Interambulacral areas very narrow, composed of a mosaic of small polygonal plates. Ambulacral rays very prominent and narrow, strongly curved, consisting of long, linear, lateral covering plates suggesting vertical palisades on lateral view, and enclosing high but very narrow ambulacral spaces. Floor plates small, each floor plate supporting two covering plates, one on each side. These floor plates overlap strongly in a proximal direction, and are so small that the bases of the covering plates must be almost in contact with each other. Peripheral band of plates distinctly defined, with larger, wide plates toward the top of the band, and with smaller, scale-like plates toward the margin, as in Ordovician species referred to *Agelacrinus* and *Lepidodiscus*.

37. **Streptaster reversata,** sp. nov.

(Plate IV, Fig. 3)

A single specimen of *Streptaster* was found 2 miles west of Million, in Madison County, Kentucky, west of trestle No. 51, in strata regarded as Middle Eden. Million is a railroad station, about 5 miles northwest of Richmond. About a mile southeast of Million, where the pike to Richmond crosses the railroad, is the home of George Million, and directly northeast of the house, along the railroad, is exposed the upper part of the richly fossiliferous Eden, directly below the poorly fossiliferous, massive, very fine grained Paint Lick or Garrard sandstone. Here the upper part of the richly fossiliferous Eden contains *Strophomena hallie*, *Platystrophia ponderosa*, *Fusispira terebriformis*, *Amplexopora septosa*, *Constellaria prominens*, *Dekayella ulrichi*, *Escharopora falciformis*, *Hemiphragma* sp., *Heterotrypa* sp., and *Perenopora vera*. Westward, along the railroad, as far as Million, a similar fauna occurs, giving place gradually to lower horizons in the Eden, on approaching the Tunnel, 1 mile northwest of Million. An eighth of a mile west of the Tunnel, at the home of Marion Newby, the lower part of the Paint Lick or Garrard sandstone is exposed far above the railroad level, while the lower parts of the Eden are seen near the track. A short distance west of this locality, *Strophomena millionensis* is found with an occasional specimen of *Trinucleus concentricus*. *Callopora sigillarioides*, *C. communis*, and *Eridotrypa briareus*, associated with *Cyclonema* and *Hebertella*, occur in the vicinity of Whitlock station; and, at bridge 51, a tenth of a mile west of the station, a small *Platystrophia* also is found. West of bridge 51, the *Streptaster* occurred, associated with *Callopora communis* and *Eridotrypa briareus*. The rock does not resemble the Greendale member of the Cynthiana formation until farther westward, so that the horizons exposed at the *Streptaster* locality may include both the Eden and the Rogers Gap member of the Cynthiana. The margin of the *Streptaster* rests upon a *Ceramoporella*, from which its Eden age was assumed. This identification of the horizon may require revision.

Anal interambulacral area quite well exposed. Left posterior ray about 14 mm. in length, of which the terminal part, for a distance of 4 mm., is parallel to the border. The right posterior ray is about 17 mm. in length. About 9 mm. from the proximal end,

the ray almost reaches the border, is parallel to the latter for a distance of 3 mm., and then curves toward the mid-length of the left posterior ray, terminating on contact with the latter at a point about 4 or 5 mm. from the proximal end of the latter. Between the recurved part of the right posterior ray and the adjacent parts of the left posterior ray, the intervening part of the posterior interambulacral area is reduced to a narrow, curved area, about half a millimeter in width, occupied by about two irregular rows of plates which are widened in a direction parallel to the rays, attaining a width of two-thirds of a millimeter. This series continues distally as a single irregular row between the strongly curved part of the right posterior ray and the much larger plates of the border.

The remaining, and much larger part of the posterior interambulacral area is bordered for three-fourths of its outline by the right posterior ray, only the proximal half of the left outline being in contact with the left ray. This part of the area is 8 mm. in length and slightly over 3 mm. in width. The anal pyramid occupies practically the entire width of the interambulacral area, between 2 and 5 mm. from the proximal ends of the posterior rays. The length of the pyramid is about 3 mm. and its width, 2.5 mm. About thirteen plates belong to this anal pyramid, converging toward the center, but it is not certain that all of them actually reached the center, Perhaps five of these plates merely act as supports to those lying nearer the center, but this can be determined only from other specimens. The interambulacral plates covering that part of the area which lies on the proximal side of the anal pyramid, all are of very small size. On the distal side of the pyramid, the interambulacral plates vary very much in size. The two largest attain a diameter of 0.75 mm. The next in size scarcely attain a diameter 0.5 mm., while most plates vary between 0.25 and 0.33 mm. All of these plates are more or less irregularly arranged, the two largest plates lying nearer the anal pyramid, along the median line of the area. The plates appear to be polygonal and arranged in a sort of irregular mosaic.

Only the distal part of the left lateral ray (No. 2) is present. This part is 9 mm. in length. The proximal part of the interambulacral area between this ray and the left posterior one is scarcely 1 mm. in width, and is occupied by 3 or 4 irregular rows of polygonal interambulacral plates, a quarter of a millimeter in diameter,

also arranged in mosaic. This interambulacral area narrows to a single row of plates distally.

Only the tip of the anterior ray, for a length of 1.5 mm., is preserved.

A single large prominent plate extends from the proximal end of the right posterior ray toward the anal pyramid. The homology of this plate is unknown.

The lateral covering plates are long and linear, and are sufficiently erect and parallel to produce the palisade effect characteristic of the genus. The longer ones slightly exceed 2 mm. in length, and about four lateral covering plates occupy a length of 2 mm. At their tips they are rather abruptly truncated, presenting a triangular transverse outline along the crest of the rays. The acute angles of these plates alternate along the median line of the rays.

Peripheral ring consisting of two zones. Of these the upper zone or inner band consists of comparatively strong plates, considerably extended in a lateral direction, but exposing only their outer edges. From these edges they are inclined toward the interior at angles of about 35 degrees with a horizontal plane. Although these stronger plates are arranged in diagonal lines, they may be said to form about five circular rows, the upper plates being considerably larger, the largest attaining a width of 4 mm. Even in the second lowest row some of the plates have a width of 2.5 mm. In the lowest row of the larger plates the width is about 1 mm. These larger plates formed the less flexible support for the upper part of the theca. Below this was the much more flexible zone of small sized marginal peripheral plates, also arranged in diagonal rows, consisting each of about six plates. The latter vary in size and form from small sized plates, laterally extended, to those of much smaller size, vertically elongated, like the vertical scales of the cup of an acorn. The latter fit snugly against the bryozoan surface upon which they rest.

Although only the posterior half of the specimen is preserved it presents the characteristic features of this half in a very satisfactory manner. The reversed curvature of the right posterior ray will distinguish this species from any other hitherto described.

38. The Thecal Plates of Cystaster and Hemicystites

In *Hemicystites stellatus,* Hall (pl. VI, figs. 6A, B), the interambulacral and marginal plates are imbricating. In *Cystaster granulatus,* Hall (pl. VI, figs. 5A–D) the theca consists of a mosaic of minute polygonal plates, distinctly defined but irregularly arranged. These plates ought to show distinctly in specimens magnified to the extent of figure 5A on plate VI, and should show even on the originals of figures 5B and C, if well preserved and thoroughly cleaned. In a specimen of *cystaster granulatus,* 7.5 mm. in width, the diameter of the thecal plates varied between one-fourth and one-third of a millimeter in the interambulacral areas, and between one-fourth and one-fifth of a millimeter on the lower half of the thecal sac. The specimen appears to have been attached at the base.

In *Cystaster* there is no indication of a peripheral ring. In *Hemicystites carnensis,* however, which is only an early form of *Hemicystites stellatus,* the weathered surface (lower part of fig. 2A on pl. III) clearly indicates the presence of large, nearly horizontal plates along the margin which represent the beginning of a peripheral ring; and in those specimens of *Hemicystites* which have the peripheral border extended, the smaller marginal plates are seen to be already differentiated.

On the theory that the *Agelacrinidae* represent forms derived from some cystid source, *Cystaster* evidently presents the most primitive form, as pointed out by Bather. Judging from figure 5D on plate VI, the form was only beginning to assume a sessile habit. *Hemicystites,* on the contrary, shows this sessile habit fully developed. Both forms appear closely related. Squamose imbricating plates are unknown among the true cystids; they can be regarded only as later developments from a primitive stock with a mosaic of polygonal, non-imbricating plates. Imbrication was due to dislocation in consequence of the species taking on a sessile habit. It probably originated at different times and in different lines of descent. Hence, the intimate relationship of *Hemicystites* to *Cystaster,* of *Streptaster* to such forms as *Agelacrinus pileus* (see fig. 1, on pl. II), and of *Agelacrinites* (fig. 3 on pl. VI) to *Lepidodiscus* (fig. 2A on pl. VI).

39. **Hemicystites carnensis,** sp. nov.

(*Plate III, Figs. 2 A, B*)

Two specimens of *Hemicystites* were found 20 feet above the level of the Ohio River on the creek flowing through Carntown, in the northeastern edge of Pendleton County, Kentucky. They occurred on the same rock fragment at the *Strophemena vicina* horizon, in strata containing *Platystrophia colbiensis*, a variety of *Plectambonites sericea*, *Dalmanella bassleri*, *Callopora multitabulata*, *Prasopora simulatrix*, *Prasopora falesi*, *Eridotrypa mutabilis*, and *Eridotrypa trentonensis*. The horizon belongs apparently to the top of the strata just beneath the Brannon siliceous limestone as exposed in central Kentucky, near Frankfort.

At Frankfort, a fine grained, siliceous limestone occurs about 50 or 60 feet below the top of the upper or Benson division of the Paris bed. This limestone, called the Brannon member, is of great paleontological interest. In and just beneath this layer are found *Strophomena vicina*, *Dinorthis ulrichi*, and *Stromatocerium pustulosum*, species found also at a higher horizon, in the Cornishville layer. This is the horizon also for *Brachiospongia*, various species of *Pattersonia*, the form described as *Chirospongia wenti*, and other sponges not known from any other horizons. The immediately underlying strata are included by Ulrich in the Wilmore, while Miller, in his original description of the term, did not draw the line limiting the top of the Wilmore until at least 40 feet lower, where *Dalmanella bassleri* ceases to be abundant. It is to the upper part of the Wilmore, as defined by Ulrich, that the *Strophomena vicina* horizon at Carntown is assigned.

The chief interest in *Hemicystites carnensis* is due to the fact that hitherto only two species of this genus were known: *Hemicystites parasiticus* from the Rochester shale at Lockport, New York, and *Hemicystites stellatus*, from the Fairmount division of the Maysville, at Cincinnati, Ohio. *Hemicystites carnensis* brings the origin of this genus down to a much earlier horizon, and places the genus among those of long duration.

Two specimens, discoidal, almost circular, faintly pentagonal, 7 mm. in diameter. The theca rises abruptly at the side for a distance not exceeding two-thirds of a millimeter. Rays prominent, rising about half a millimeter above the general surface of

the theca; subclavate in outline, with the greatest width, 1 mm., not at mid-length, but about one-third of the length of the ray from the end. This sub-clavate outline is noticeable especially in the case of the anterior ray, opposite the anal area. The posterior rays, on each side of the posterior interambulacral area, branch off not from the center of the theca but from near the base of the lateral rays, on their posterior sides, thus producing wider interambulacral spaces between the proximal ends of the posterior rays than between any of the other rays. Only the lateral covering plates are visible along the rays; nine or ten on each side of the anterior ray, seven or eight on each side of the lateral rays, and eight on each side of the posterior rays. These covering plates are slightly imbricated and their tips alternate along the median line of the rays. Interambulacral plates about as numerous as in *Hemicystites stellatus*. Anus nearer the central part of the posterior area than indicated in the published figures of that species. Upper part of the margin strongly reënforced by large flat plates, the lower margins of which slope gently toward the center, only their upper edges being exposed exteriorly.

On comparing these specimens with *Hemicystites stellatus*, little is found to distinguish them. Compared with the type of that species, the rays are narrower and less elliptical, and the interambulacral areas are correspondingly wider. The trimerid origin of the rays also appears to be more in evidence, owing to the wider separation between the posterior rays. A wider acquaintance with the range of variation of *Hemicystites stellatus* is likely to decrease, rather than increase, the supposed differences of *H. carnensis*. The number of Fairmount forms represented by closely similar precursors among Trenton species is a matter of interest, and this number is continually increasing.

Description of Several Lepadocystinae

40. The Migration of the Anus of the Glyptocystidae

Bather, in his treatise on the Echinoderma, in 1900, and again in his *Caradocian Cystidea from Girvan*, Figure 45, in 1913, determined the probable path of the gut along the inner wall of the theca in the primitive *Glyptocystidae* by noting where the gut pore-rhombs failed to appear in any known species. The second figure is re-

produced on this page as Figure 2. In *Lepadocystis,* from the upper Richmond of Indiana, the gut apparently has been raised sufficiently to cause the disappearance of the pore-rhombs on the middle parts of plates 12, 11, 10, and 14; also on the lower parts of plates 10 and 14 and on the adjoining upper parts of plates 8 and 9. This lifting of the gut was accompanied both by a lifting of the anus and also by a shifting this anus toward the right. The anus was lifted from between the second and third row of plates to a position within the third row, pushing plate 13 upward to a position between plates 18 and 19, and crowding plates 18 and 17 toward the left, altering their primitive pentagonal outline to

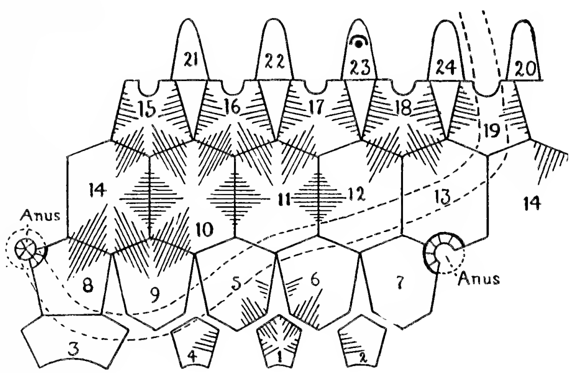


Fig. 2. The actual distribution of all pore-rhombs known with certainty in the Glyptocystidae, showing how a space is left clear where the gut may be supposed to have pressed against the thecal wall. Copied from Bather, in Caradocian Cystidea from Girvan, 1913, page 437.

a more quadratic form. The migration of the anus toward the right appears to be connected with the dextral curvature of the gut within the visceral cavity. At any rate, there does not seem to be any cystid in which the anus may be supposed to have travelled toward the left.

In *Brockocystis,* from the Silurian of Ontario, the anal area occupies a position similar to that of *Lepadocystis,* but it is larger, and has not thrust plate 13 as far upward, so that this plate does not come in contact with the sides of plates 18 and 19 but only with their lower margins. The absence of the pore-rhomb on plates 11–17 suggests a local upward flecture of the gut in this area.

41. **Lepadocystis,** Carpenter, generic characteristics

Lepadocystinae, with oval theca composed of plates arranged as follows:

Basal row, with plates 4, 1, 2, 3.

Second row, with plates 5, 6, 7, 8, 9.

Third row, with plates 10, 11, 12, and 14. Plate 13 has been elevated sufficiently to be chiefly in the fourth row.

Fourth row, with plates 16, 17, 18, 19, and 15. Also most of plate 13.

Fifth row, with plates 22, 23, 24, 20 and 21.

Column obliquely attached at the base, with anal area on that side of the theca which has the longest curvature.

Anal area prominent, between plates 7, 8, 13 and 14.

Pectinirhombs on plates 1–5, 10–15, 11–17, 12–18, and 14–15, with more or less discrete areas of a lunate form, usually deeply impressed on the convex margin, and crossed by rather numerous dichopores.

Ambulacra five, reclining upon the surface of the theca and terminating usually at, or slightly beyond, the middle of plates 15, 16, 17, 18, and 19.

Genotype, *Lepocrinites moorei*, Meek.

The generic term *Lepadocystis* was proposed by Carpenter, in 1894, in vol. 24 of the *Journal of the Linnean Society*, Zoology, on p. 10, in the following words:

Another interesting and geologically earlier form is *Lepocrinites* (*Lepadocrinus*) *Moorei* of Meek, from the Cincinnati group of Indiana, which differs from *L. Gebhardi* in having five ambulacra and a pore-rhomb on plates 10–15, in addition to those on 1–5, 12–13, and 14–15. I am inclined to regard these characters as of generic value, and would propose therefore to distinguish Meek's species by the name of *Lepadocystis*.

To this list of pore-rhombs, as given by Carpenter, should be added that on plates 11–17, as already stated above. The latter had escaped the attention of Meek, owing to the imperfect cleaning of this part of the type specimen.

The anus has been shifted upward and toward the right from its archetypal position between plates 7, 8, and 13, so as to come in contact also with plate 14. In this process, plates 7 and 8 have

become elongated vertically, and plate 13 has been lifted until in contact with the sides of plates 18 and 19, instead of touching them only at their lateral bases.

42. **Lepadocystis moorei,** Meek

(*Plate 5, Figs. 1 A, B, C, D*)

The type of *Lepadocrinites moorei*, Meek, is preserved in the Museum of Earlham College, at Richmond, Indiana. It was found by H. C. Balls, a student at the college, and submitted by Prof. Joseph Moore to Meek. Through the courtesy of Prof. A. D. Hole, I was permitted to examine this type.

The following is an attempt at an independent analysis of the plate system of the type, which is intended to show where the

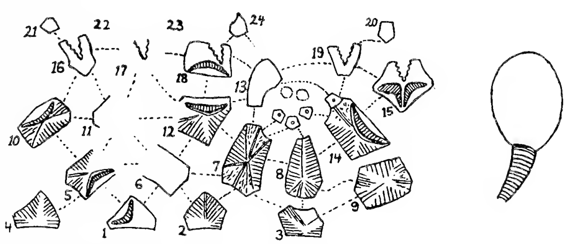


Fig. 3. Diagram of type of *Lepadocystis moorei*. Of plate 17, only the path of the ray is indicated. The natural size of the specimen is indicated by an outline drawing at the right of the diagram. Type preserved at Earlham College, Richmond, Indiana.

details are clearly defined and where they are imperfectly exhibited by the type specimen. This diagram differs but slightly from that presented by Bather in his volume on the Echinoderma, forming Part III of Lancaster's *Treatise on Zoology,* published in 1900.

In this diagram, the character of the surface ornamentation, consisting chiefly of parallel lines radiating in different directions, is indicated, wherever preserved. The ornamentation of plate 13, and of plates 15 to 19, probably was very faint or practically absent. The outlines of plates 11 and 17, and those of the adjacent parts of plates 5, 6, and 12 are so poorly defined that they can not be indicated with exactness. The surface ornamentation of

plates 11–17 was detected only after their presence had been discovered on other specimens on which the surface of these plates was well preserved. A small fragment, probably belonging to plate 13, is drawn in this analysis as though a part of plate 14. This is the fragment drawn by Meek, in his diagram of this specimen, printed on one of the pages interleaved between the index and the numbered plates, at the close of vol. i, of the *Paleontology of Ohio*, in 1873, as though it were a fifth plate in contact with the anal area.

The anal area is composed of two circles of plates, of which the type preserves only three plates belonging to the lower part of the outer circle. The two plates in contact with plate 7 are pentagonal and bear a central tubercle, as described by Meek. A third plate, of a similar character, is in contact with plate 14. Judging from other specimens, the so-called central tubercle, on each of the three lower plates of the anal area may be regarded merely as a continuation of the parallel line ornamentation belonging to the top of plates 7 and 8. From other specimens it is known that the plates forming the top and upper left hand sides of the outer circlet of plates, in the anal area, are of much smaller size than the lower plates, thus reducing the width of the upper part of the outer circlet. The two plates indicated in the upper part of the anal circle therefore are incorrect, and should be replaced by a row of much smaller plates.

The ambulacral arms are clearly outlined. Those parts of the thecal plates upon which they rest are flattened, but not indented or depressed. The arms or ambulacra are longer, more linear, and narrower at their proximal extremities than indicated by Meek's Figure, 4c. Ambulacral plates with facets for attachment of the brachioles at alternate sutures of the ambulacral plates. At these areas of attachment the two adjacent plates form a single rounded low knob, projecting beyond the lateral contour of that part of the plates which intervenes between the points of attachment for the brachioles. The side of each knob is impressed by a single facet. Ambulacralia present but not clearly defined.

In the museum at Earlham College, there is a second specimen of *Lepadocystis*, apparently from the same locality and horizon as the type of *Lepadocystis moorei*—namely, from the Whitewater member of the Richmond, at Richmond, Indiana. It differs in its smaller size, and in the surface ornamentation being more

stellate, probably owing to the retention of only the stronger, central ones among the parallel lines characterizing the type of the species. The character of this stellate ornamentation is indicated in the following analysis of the plate system.

The stellate lines radiate from the center of the plates to their outlines, chiefly to the middle of the sides, but, in part, also to some of the angles of these plates. This stellate ornamentation appears to be characteristic of small sized specimens and may indicate the presence of a distinct variety of this species. For the present it is regarded merely as indicating immaturity.

The most interesting feature of this smaller specimen is the excellent preservation of the surface and of the outline of those plates which, in the type of *Lepadocystis moorei*, were scarcely decipherable. The pectinirhomb on plates 11–17 is well preserved, although distinctly smaller than those on plates 1–5,

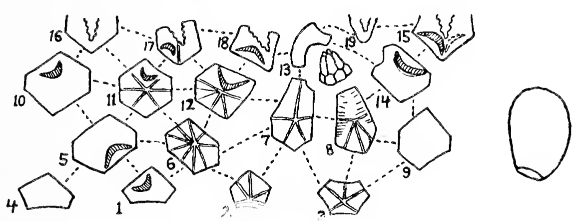


Fig. 4. Diagram of *Lepadocystis moorei*. The natural size of the specimen is indicated by an outline drawing at the right of the diagram. Museum of Earlham College, Richmond, Indiana.

10–15, 12–18, and 14–15. The anal area is surrounded by plates 7, 8, 13, and 14, excluding 19 from any contact with this area. The plates of the anal area are arranged in two circles, of which the outer circle consists of small polygonal plates. Only a part of these plates, those forming the lower and lower right hand part of the outer circle, are exposed. The smaller plates, completing the remainder of the circle, where it is narrower, are not seen. The central circle consists of more triangular plates, evidently meeting at the center in the form of a prominent cone, but, owing to the strong inclination of this cone toward the oral end of the specimen, only three of these triangular plates are well exposed, and the total number can not be determined. In other specimens they are not as narrow as here indicated. The outlines of plates 20 to 24 cannot be distinguished with certainty.

A third specimen of *Lepadocystis,* also in the Museum of Earlham College, is contained in a rock fragment containing large numbers of *Zygospira modesta* and some branching bryozoan, apparently *Bythopora delicatula.* These forms indicate the Richmond origin of the cystids, and eventually may lead to a rediscovery of the exact horizon.

A fourth specimen of *Lepadocystis,* belonging to that part of the Dyer Collection which was not sold to Harvard University, has been acquired recently by Miami University, and was obligingly loaned to me by Professors S. R. Williams, and W. H. Shideler. It was obtained from the upper part of the Richmond, at Richmond, in Indiana. This specimen also presents the radiate surface ornamentation already noted in the smaller sized specimen here

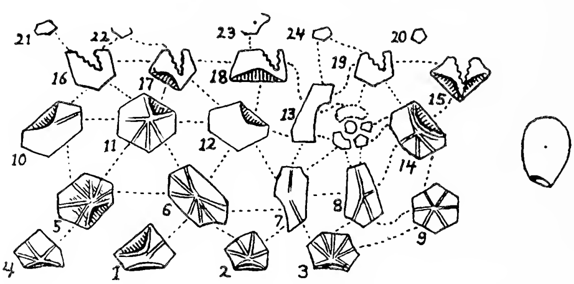


Fig. 5. Diagram of *Lepadocystis moorei.* The natural size of the specimen is indicated by an outline drawing at the right of the diagram. Museum of Miami University, Oxford, Ohio.

described from the Earlham College collection. The character of this ornamentation is indicated in the following analysis of the plate system.

The pectinirhomb on plates 11–17 again is well defined. The outline of plate 7 certainly is aberrant, and should be more like that illustrated in the two preceding diagrams. Possibly there is a break in the plate near its lower left hand margin, causing a misinterpretation of its outline here. Only the larger plates of the outer circle forming the anal area can be distinguished. The largest of these is in contact with plates 8, 7, and 13, and evidently is the anchylosed representative of two of the plates figured in the type of the species. The upper part of the outer anal circle is known, from other specimens, to have been occupied by a row of

very small plates. The space belonging to the inner circle is occupied by a circular mass, half a millimeter in diameter, within which it is impossible to distinguish any individual plates. Possibly this part of the anus was more or less retractile. It is very probable that the outline between plates 13 and 19 was drawn incorrectly in this diagram. Judging from other specimens, plate 19 never should be in contact with the anal area, in this species, and the lower left hand part of plate 19, as illustrated in this diagram, unquestionably belongs to the adjacent part of plate 13. The line of separation between plates 19 and 13 should be drawn along the left border of the ambulacrum or subvective system. Judging from other specimens, the difficulty of distinguishing the outline between plates 19 and 13 arises from the fact that this outline frequently is covered by the left margin of the ambulacrum, which does not cross the middle of plate 19, as here drawn in the diagrams, but traverses the left half or left two-thirds of the plate instead. In each of the diagrams here presented the effort was made to interprete the specimen on the basis of what the specimen actually appeared to suggest, irrespective of every other specimen. In the case of the present diagram, the supposed outline between plates 19 and 13 probably is due to a crack crossing plate 13, and the covering up of the real line of separation by the ambulacrum crossing the left part of plate 19. Owing to the difficulty of distinguishing plates 20 to 24, the outlines here presented have little value. Stereom-folds in pectinirhombs 1–5, 12–18, 14–15, 10–15, about eleven; in pectinirhombs 11–17, about seven. These numbers disagree with the number of stereom-folds found in specimens of larger size, which resemble the type in having a parallel-line ornamentation, instead of a stellate plate ornamentation.

That part of the Dyer Collection acquired by Miami University contains also another specimen of *Lepadocystis*, with the theca broken across so as to expose the interior of one side. Interior views of pectinirhombs 1–5, and 11–17 are presented. These pectinirhombs project angularly into the interior cavity, the stereom-folds passing uninterrupted from plate to plate, and are not discrete, as on exterior view. The stereom-folds on pectinirhomb 1–5 number about eleven, and those on pectinirhomb 11–17 number seven. Both an exterior view of the column and of its area of attachment on the interior of the theca are presented. The column is rather large at its area of attachment, and tapers

rapidly. It probably was short and did not serve as a means of attachment in mature specimens.

In the Walker Museum of Chicago University there are three specimens of *Lepadocystis moorei* belonging to the Faber Collection, and numbered 9961.

Of these, one specimen, A, is defective at the base, but otherwise is remarkably well preserved (plate V, Fig. 1A, C). The ornamentation is of the parallel line character, as in the type, but certain of the lines are slightly stronger, and it is evident that by the accentuation of the stronger lines the stellate ornamentation of the smaller specimens could be derived. Of the first row of plates, only plate 1 is preserved entire. The basal parts of plates 7 and 8 are missing. The ambulacrum, which crosses the

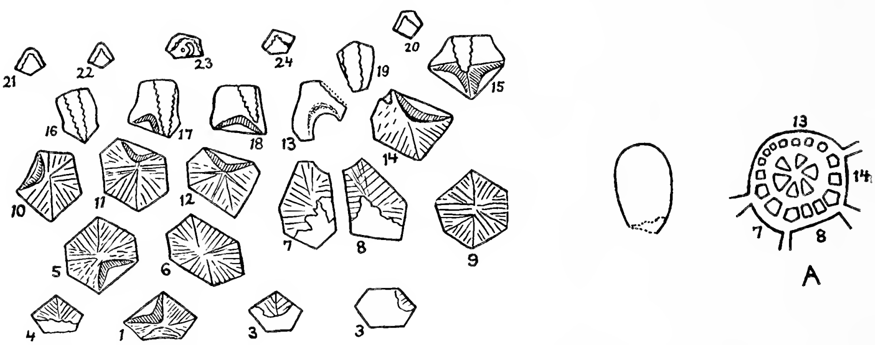


Fig. 6. Diagram of *Lepadocystis moorei*. The natural size of the specimen is indicated by an outline at the right of the diagram. *A*, diagram of anal area, in contact with plates 7, 8, 13 and 14. Specimen No. 9961A, Faber Collection, Chicago University.

left side of plate 19, slightly overlaps the adjacent edge of plate 13 and intrudes upon the upper left hand corner of plate 14, at the left of the pectinirhomb 14–15. All of the ambulacra are remarkable for their length. That on plate 16 reaches the extreme lower angle of the plate. That on 17, borders the upper right hand side of the pectinirhomb and does not quite reach the lower angle. That on plate 18 terminates in a similar position. That on 15 overlaps the tips of the adjacent angles of pectinirhombs 14–15 and 10–15. Only the lower outlines of plates 20, 21, 22, and part of 23 are faintly perceptible.

The ambulacra appear to consist of two series of plates, more or less alternating, which rest upon the theca. On plate 18, several of these ambulacral plates have dropped off, leaving slightly concave depressions. The lateral covering plates of the subvective grooves are well preserved at the proximal ends of several of the ambulacra, notably between deltoids 20 and 21, where these covering plates are seen to meet along the median line at an acute angle. Covering plates are seen also between deltoids 21 and 22 and between 20 and 23. In order to make the structure of the tegmen agree with the theory of an early trimerous structure, among the Echinoderma, leading subsequently to a pseudo-pentamerism, it is necessary, in the present species, to regard the left primary branch of the subvective system, between deltoids 21 and 23, as much abbreviated, compared with the right primary branch, between deltoids 20 and 23. From these primary branches, two secondary branches originate on the right, and two on the left, by bifurcation. The anterior primary branch does not lie directly opposite the posterior deltoid, 23, but is directed slightly to the right. (See text Fig. 7A on page 466 in this BULLETIN.) The lateral covering plates are oblong in form and very minutely striated in a vertical direction. There is no differentiation of these plates at the center so as to form a district oral group.

Stereom-folds in pectinirhombs 1–5, sixteen; in pectinirhomb 12–18, twenty; in pectinirhomb 14–15, nineteen; in pectinirhomb 10–15, sixteen; and in pectinirhomb 11–17, twelve.

The anal area (Fig. 6A) presents details not seen in preceding specimens. In contact with plate 8 are four small plates, of which the two extreme are in contact also with plates 7 and 14, respectively. Another plate of about the same size is in contact with the middle part of the anal outline of plate 7, and two additional plates are in contact with plate 14. All of the plates in contact with plate 13 are of smaller size than any of the other plates belonging to the outer circle in the anal area, especially toward the upper left hand side of this area, but the details here cannot be definitely determined. From the left side of the moderate depression within this outer circle of plates, a pyramid of small triangular plates, meeting at the center, projects, but their number is not known definitely. Judging from other specimens, the anal area has not yet been accurately worked out, or else it varies more or less in structure in different specimens.

Another specimen from the Faber Collection, 9951B (plate V, Fig. 1, B, D) presents all of the plates, and has the parallel line ornamentation of the type specimen. This ornamentation has been omitted in the following diagram.

All of the plates belonging to the first three rows are distinctly outlined, excepting plates 13 and 14, and, of these, plate 13 has been pushed up until it belongs practically to the fourth row, as already noted in the description of the genus. The right hand margin of plate 13 is concealed by the ambulacrum which traverses the left three-fourths of plate 19 and reaches a point on plate 14 opposite the middle of the anal area. The last two left hand brachioles of this ambulacrum are preserved. They consist of two series of alternating plates, about five or six in each series. Judging from other specimens, the brachioles near the proximal end of the ambulacra

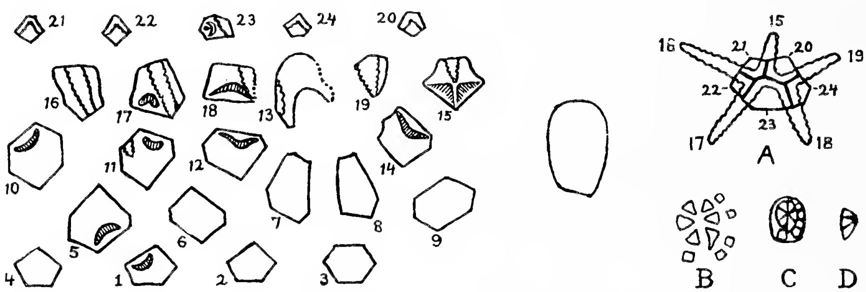


Fig. 7. Diagram of *Lepadocystis moorei*. The natural size of the specimen is indicated by an outline at the right of the diagram. *A*, Diagram of the ray system; the rays follow the sutures between plates 20–24, and terminate usually on plates 15–19. *B*, Diagram of anal pyramid and of part of the surrounding circlet of plates. *C*, The same plates, in natural position. *D*, The anal pyramid, viewed from the side. Specimen No. 9961B, Faber Collection, Chicago University.

probably were longer. Owing to the ambulacrum just mentioned, the suture between plates 13 and 14 is concealed. On plate 15, the ambulacrum reached the middle of the plate, at the junction of the two adjacent angles of the pectinirhombs. This is the anterior ambulacrum, and is always the shortest. On plate 16, the ambulacrum crosses only slightly to the right of the middle of the plate and passes a short distance beyond the suture between plates 16 and 17. On plate 17, the ambulacrum crosses the entire length of the plate, grazing the upper right hand margin of the pectinirhomb, and at least one of the ambulacral plates reached

the adjacent angle of plate 12. Several of the ambulacral plates have dropped off from the theca. Of the ambulacrum on plate 18, only the proximal plates remain. The others have dropped off from the theca, but the flattened area on the latter indicates that the right side of this ambulacrum formerly covered the suture between plates 18 and 13, and that the tip of this ambulacrum reached at least the lower right hand angle of plate 18. From the center of the tegmen, the anterior ambulacrum, on plate 15, extends 3.5 mm.; the right anterior ambulacrum, on plate 16, 6 mm.; the right posterior ambulacrum, on plate 17, 5.5 mm.; the left posterior ambulacrum, on plate 18, 6.5 mm.; and the left anterior ambulacrum, on plate 19, 7 mm. Judging from the elevations at the attachments for the brachioles, the number of brachioles on each side of the anterior ambulacrum were about three or four; on each side of the right anterior ambulacrum, about five or six; on each side of the left posterior ambulacrum, about six or seven; and on each side of the left anterior ambulacrum, also about six or seven. The right posterior ambulacrum is not sufficiently preserved, but judging from its length it probably had five or six brachioles on each side.

The outlines of the deltoids, or plates belonging to the fifth row, are more readily detected in this specimen than in any other, and the result is indicated in the accompanying diagram.

Stereom-folds in pectinirhomb 1–5, unknown; in pectinirhomb 12–18, nineteen; in pectinirhomb 14–15, twenty-one; in pectinirhomb 10–15, about sixteen; and in pectinirhomb on plates 11–17 about ten or eleven.

At the lateral ends of the pectinirhombs, the stereom-folds often are continuous across the suture lines, exteriorly as well as interiorly, but along the middle of the rhomb there is a lens-shaped area, including parts of both plates along the suture lines, in which the folds are not visible. From this lens-shaped area, the stereom-folds on plates 10, 11, 12, and 14 slope downward, and on plate 5 slope upward, both the upper and lower lip of the fold area being sharply defined by a raised border. On plates 15, 17, and 18 the stereom-folds slope upward, and here only the upper lip is sharply defined. In a similar manner, the stereom-folds on plate 1 slope downward and are strongly defined only along the lower lip.

The anal area presents evidence of at least two circles of plates, of which the interior one forms the conical pyramid. Apparently

at least six plates take part in this cone. The outer circle consists of larger plates where in contact with plates 7 and 8, of medium sized plates where in contact with plate 14, and of small plates where in contact with plate 13. The details are more or less obscured.

A third specimen in the Faber Collection, 9961C, is badly weathered, but for that very reason presents an excellent view of the outlines of plate 19, all of the ambulacral plates having dropped off. The suture between 13 and 14 also is well exposed, and there is no doubt as to the exclusion of plate 19 from contact with the anal area. Plate 19 is never in contact with plate 18. Some of the deltoids are very distinctly outlined along parts of their margins. A brachiole attached to one of the proximal facets of the ambulacrum crossing plate 16 has a length of more than 3 mm. The most interesting part, however, is the anal area, which again presents an outer and inner circle of plates. The inner circle forms the conical pyramid, and apparently consists of nine plates, although the number may have been only seven. The outer circle has the largest anal plates along plates 7 and 8, with medium sized plates along plate 14 and the immediately adjacent part of plate 13. The remaining anal plates, along plate 13, form a very narrow row of very small plates. Perhaps the total number of anal plates in contact with plate 13 is as great as fifteen or sixteen. From this the very small size of th smallest plates may be inferred. The circular area of attachment of the column has an interior diameter of 2.3 mm., and an exterior diameter of 3.2 mm.

43. **Brockocystis,** Gen. nov.

This genus is very closely related to *Lepadocystis*, but differs in the following particulars:

There is no pectinirhomb on plates 11–17. Plate 19 is in direct contact with plate 18, at least along the upper lateral margins of the two plates. Plate 13 has not been raised sufficiently to separate plates 18 and 19, but comes in contact only with their lower lateral outlines. Anal area large. The ambulacral or subvective system is much more restricted, the ambulacra extending only short distances over plates 16 and 17, and not reaching the base of plates 18 and 19. The number of brachiole facets is very small, and although the brachioles are missing it may be assumed

that these were correspondingly stout. The ornamentation is entirely different, consisting of an irregular network of interlacing raised lines.

GENOTYPE, APIOCYSTITES TECUMSETHI, BILLINGS

Genus named in honor of the distinguished head of the Geological Survey of Canada, Dr. R. W. Brock.

44. **Brockocystis tecumsethi,** Billings

(Plate V, Figs. 2 A, B, C)

Apiocystites? Tecumseth, Billings. Catalogues of the Silurian fossils of the Island of Anticosti, with descriptions of some new genera and species. Geological Survey of Canada. Montreal, p. 91. 1886.

The original description of this species follows:

This species is proposed for a Cystidean collected by Prof. R. Bell and H. C. Vennor, on Manitoulin Island in 1865. Only detached plates and fragments of the column were found. Most of the plates have a large hemispherical protuberance which occupies all of the plate, except a narrow flat border all around. The rhombs consist of two separated triangular spaces, their bases separated as in *A. elegans*, Hall. The column has from three to four lines in length at the point of attachment, encased in an ovoid mass which is either a secretion of the column itself, or a parasitic zoophyte, or, perhaps, a sponge. The surface of this part, as well as that of the tumid part of the plates, is covered with small polygonal pits. Near South Bay, Manitoulin Island; Prof. R. Bell, H. G. Vennor.

The detached plates of the type series were shown me in 1904 by Mr. Whiteaves. Similar plates are very common not only on the surface of the high hill southwest of Manitouaning but also along the road between Gore Bay and Kagawong, at a crossing over a wet weather stream, exposing a rocky bottom, about half a mile east of Ice Lake. As remarked by Schuchert (*On Siluric and Devonic Cystidea and Camarocrinus*, 1904, p. 212): "Until the theca of A.(?) tecumseth is known, this can not be regarded as an established species." Fortunately, an excellently preserved specimen was found by the writer near the top of the Cataract limestone at the locality east of Ice Lake. It forms No. 8447 in the collections, of the Canadian Geological Survey, in the Victoria

Memorial Museum, at Ottawa, and forms the basis of the following very full description.

Plates arranged as in the following diagram.

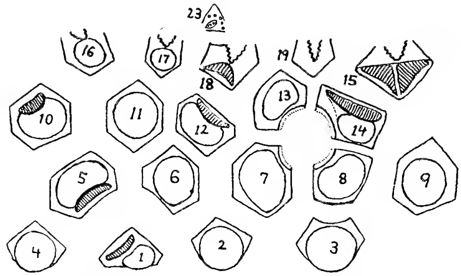


Fig. 8. Diagram of *Brockocystis tecumsethi*, Billings. The outlines of plates 20-24 could not be determined with accuracy. The outlines of the hemispherical protuberances are indicated. Specimen No. 8447, in the collections of the Geological Survey of Canada.

The plates of the fifth row are practically concealed under the plates belonging to the ambulacral or subvective system. There apparently is a trace of the outline between deltoid 23 and plate 18, but the remainder of the outline of plate 23 is not known and no deductions must be drawn from the outline of this plate in the diagram, which represents merely the space between the overlapping ambulacra. The plates bearing the large hemispherical protuberances are indicated in the diagram. Those on plates 1 and 13 are small. Those on plates 2, 3, 4, 14, 16, and 17 are of medium size. The remainder are large. No protuberances occur on plates 18, 19, or 15, excepting the triangular supports for the ambulacra. On these three plates, also, the reticulate ornamentation is faint or obsolete.

Pectinirhombs more or less discrete along the suture lines separating the two plates forming the rhomb. The lower boundary of the rhomb on plates 12, 14, and 10 is strongly defined by a vertical wall formed by the adjacent part of the hemispherical protuberances on these plates. The upper part of the stereom-fold area on the same plates also is sharply defined, but only by a sharp striation. The boundaries of the fold areas on plates 15 and 18 are distinct, but not defined by conspicuously elevated striae or walls. The pectinirhomb on plates 1–5 is strongly defined by a vertical wall along its upper outline on plate 5, it is strongly

defined, but by much less conspicuously raised borders, on both sides of suture separating plates 1 and 5, and is inconspicuously bordered along its lower margin on plate 1. Stereom-folds on plate 5, about eighteen; in pectinirhomb 12–18, about twenty-three; in pectinirhomb 14–15, about twenty-three; and in pectinirhomb 10–15, about fourteen or fifteen.

Anal area circular, about 5 mm. wide and perhaps a little longer. Anal plates missing, but evidently supported on a flange along the lower part of the opening formed by plates 7, 8, 13, and 14.

At the base of the theca, the protuberances on plates 1, 2, 3 and 4 project below the level of attachment of the column. This is true especially of plates 2, 3, and 4. The outer diameter of the area of attachment is 5.3 mm. and the inner diameter is about 3.2 mm.

Column very short, the columnals fused together and surrounded by a sclerodermous mass having a pyriform outline and ornamented at the surface with the same pitted and reticulated structure as the plates of the theca. The length and width of the fused column together with the surrounding sclerodermous material usually is less than 10 mm. At the lower end it is narrowed to a flattened surface, suggesting an early statozoic stage. The diameter of this flattened surface usually varies from 2 to 3 mm., but sometimes equals nearly 4 mm. Through the center of the sclerodermous mass there passes a vertical, funnel-shaped opening, interpreted as representing the column. The first columnal evidently was wide, corresponding to the broad area of attachment at the base of the theca. The second columnal was conspicuously smaller, usually not exceeding 3 mm. in width, if the structure has been interpreted correctly. The third columnal was still smaller, varying from 1.5 to 2 mm. in diameter. Beginning with the third, the remaining columnals form the less rapidly tapering or more tubular part of the "funnel." In one specimen this funnel diminishes in width from 2 to 0.7 mm. in a length of 7 mm., including 15 columnals. Of these columnals, the first 8 occupied a length of 4 mm. and the next 7 of 3 mm. Each columnal tends to be surrounded by two transverse ridges separated by a transverse groove. That part of the sclerodermous covering which lines the column, and also that part which forms the pitted and reticulated surface, is solid. The intervening part of the sclerodermous mass often is less solid,

and in one specimen, this space was transversed by thin circular sheets of sclerodermous material, one sheet for each columnal, extending from the column diagonally upward toward the pitted surface. These thin annular sheets are fluted radiately, the fluting possibly having some connection with the reticulated surface markings. Adult animal probably eleutherozoic.

Ambulacral or subvective system coarse, confined to the extreme top of the theca. Ambulacral grooves strong, about a millimeter wide at their proximal ends, uniting at the center of the tegmen in an oral orifice nearly 2 mm. wide and a little over 1 mm. in diameter in an antero-posterior direction. This orifice descends into the theca, but probably was entirely concealed by covering plates, as in the closely related genus, *Lepadocystis*. No trace of covering plates, however, remains.

The trimerous origin of the ambulacral system is clearly defined. The anterior ambulacrum is directed toward the right of a line drawn perpendicular to the line connecting the terminations of the lateral primary ambulacral grooves. It extends 4.5 mm. from center of the tegmen almost to the adjacent proximal angles of the pectinirhombs on plate 15. The lateral primary grooves bifurcate about 1 mm. from the oral passage or 2 mm. from the center of the tegmen. The right anterior ambulacrum terminates on plate 16, about 6 mm. from the center of the tegmen, and is almost a direct continuation of the right primary division of the ambulacral system. The right posterior ambulacrum curves strongly backward and toward the left, terminating on plate 17, about 5.5 mm. from the center of the tegmen. The left posterior ambulacrum is directed diagonally backward to plate 18, terminating about 7 mm. from the center of the tegmen. The right anterior ambulacrum curves forward to plate 19, and terminates 7 mm. from the center of the tegmen. All of the ambulacra are broad at their proximal ends and bluntly triangular in form. In each case one or more ambulacral plates are missing. Judging from those remaining, the number of brachioles on each side of each arm usually was two, but may in some cases have equalled three, or may even have been reduced to one on one side. The proximal one of these brachioles, judging from the facets, probably was coarse, and the distal brachiole, at least smaller.

43. **Brockocystis clintonensis,** Parks

(*Lepadocystis clintonensis, Parks. American Journal Science, vol. XXIX, 1910, p. 404, Figs. 1, 2*)

This species unquestionably is congeneric with *Brockocystis tecumsethi*. It not only has the same diagrammatic arrangement of the plates but also a closely similar form of ornamentation. The type specimen, No. 372C1, in the Museum of the University of Toronto, is 15 mm. high and 10 mm. wide, while the height of *Br. tecumsethi* is 23 mm. The type of *Br. clintonensis* was found at the Forks of the Credit River, Ontario, in the Cataract formation. The plates are not elevated at the center into large hemispherical protuberances, but follow merely the general convexity of the theca. The column is round and tapers distally. The first ten columnals, at mid-length, show a sharp transverse crest and occupy a length of about 7 mm. Distally, the columnals increase in length, and beyond the tenth columnal the crest becomes less defined and the columnals become barrel-shaped. The seventeenth columnal is 2 mm. long and about 2 mm. wide.

44. **Brockocystis huronensis,** Billings

Apiocystites huronensis, Billings. Catalogues of the Silurian Fossils of Anticosti, 1866, p. 91, fig. 28.

Apiocystites (?) *huronensis*, Schuchert. On Siluric and Devonic Cystidea and Camarocrinus. Smithsonian Miscellaneous Collections, vol. 47, part 2, 1904, p. 212.

The original description is as follows; in this description the numbers of the plates have been added in brackets.

The specimen is partly buried in stone and its generic characters cannot be ascertained. The plates are moderately convex, depressed at the sutures. The rhomb at the base is one-half on a basal plate (plate 1), and one-half on a plate (plate 5) of the second series. In the upper part is another rhomb, one-half of which is on a plate (plate 10) of the third series, and the other apparently on a plate (plate 15) of the fourth. The lower half, however, of the basal rhomb (plate 1), and the upper half of the upper rhomb (plate 15) are not distinctly seen. As no arms are visible, it seems certain that this species is not a true *Apiocystites*. The position of the rhombs also favors this view. The specimen was

found near Cabot's Head, on the shore of Lake Huron. Clinton; or Niagara formation (at present called Cataract formation). A. Murray, Esq.

From the accompanying figure (fig. 28) it is evident that in addition to the plates mentioned, plates 4 and 9 also are present. The column is round, and tapers distally. Only the proximal columnals are present. Reticulate markings are not in evidence on the plates of the theca, but the specimen evidently is more or less weathered. The height of the complete theca probably was about 16.5 mm., agreeing in this respect quite closely with *Brockocystis clintonensis*, Parks, from the same horizon. From the latter species, *Brockocystis huronensis* appears to differ chiefly in its more convex thecal plates. Evidently more material is necessary before *Brockocystis huronensis* can be considered an established species.

Judging from present knowledge, *Brockocystis* is confined to the Cataract formation, while *Lepadocystis* is known only from the upper Richmond.

PLATES

PLATE I

Fig. 1. Agelacrinus holbrooki, James. *A*, Figure of type. *B*, Outline, side view of specimen, showing dome shaped elevation; figures accompanying the description of the species in the Journal of the Cincinnati Society of Natural History, vol. x, p. 25, in 1887. *C*, anal region much enlarged, showing the squamous plates of the margin; the termination of the two posterior rays, Nos. 1 and 5, with both lateral and central covering plates; the anal pyramid, surrounded by small plates; copy of figure published by Clarke in New Agelacrinites, p. 189, in 1901, forming No. 40744, of the U. S. National Museum. *D*, Lateral outline of specimen No. 1004, in the James collection, at Chicago University, regarded as the type of the species although not oriented as in the published figure of the latter; the distal parts of the posterior rays, Nos. 1 and 5, and part of the anal pyramid are preserved in this specimen; the drawing is intended to indicate the slumping of the theca owing to its supposed attachment to a slanting valve of Rafinesquina, the proximal part of the right ray, No. 4, being directed toward the upper part of the slanting surface. *E*, five floor plates from the anterior ray of specimen 1004, the lower three of which are parallel to the peripheral ring, and the upper two belong to the same ray, in a proximal direction; at the base of the drawing, the exposed parts of two covering plates are indicated; at the top, the basal extensions of three covering plates are represented; transverse sections of two of the floor plates are presented. *F*, A lateral covering plate, and lateral view of the same to indicate its curvature, f ·om specimen 1004.

Fig. 2. Agelacrinites beecheri, Clarke. Floor plates seen from below. Copied from figure accompanying the original description, in New Agelacrinites, in Bulletin 49, N. Y. St. Mus., on page 195, in 1901. Apparently only long enough for one lateral covering plate on each side of the floor plate. No. 4001-1, plastotype, N. Y. State Museum.

Fig. 3. Agelacrinus faberi, Miller. *A*, lateral view; *B*, view from above; copies of the figures accompanying the original description, in Journal, Cincinnati Soc. Nat. Hist., vol. xvii, on plate 8, in 1894. The type forms No. 8821 in the Faber collection, at Chicago Univ. *C*, floor plates of the type, accompanied by a cross section of the same.

Fig. 4. Agelacrinus warrenensis, James. *A*, natural size; *B*, same specimen enlarged; copies of figures accompanying the original description, in The Paleontologist, No. 7, plate II, in 1883. Regarded as young specimen of Agelacrinus cincinnatiensis, poorly preserved.

Fig. 5. Agelacrinus pileus, Hall. *A*, central part of figure published by Miller and Faber, in Journal of Cincinnati Soc. of Nat. Hist., vol. xv, on plate I, in 1892. On that plate, the proximal part of the anterior ray is directed diagonally downward toward the right. In the figure here presented, this part of the ray is directed upward, and the rays are numbered. A part of the lower surface of the oral face of the theca is illustrated. Remnants of floor plates are seen at the proximal ends of rays 3 and 2. Most of the proximal floor plate forming that part of the rim of the substomial chamber which arches across ray 4, as seen from below, is missing. The proximal floor plates forming that part of the rim arching across rays 5 and 1 are entirely absent. The lateral covering plates with their basal extensions are shown. Also three of the peristomial plates, the two anterior rhomboid plates and the posterior quandrangular plate, with their dovetailing ridges, as seen from below. This specimen forms No. 8825 in the Faber collection, at Chicago University. *B*, Peristomial plates and some of the adjoining plates of specimen No. 1192-2-A, belonging to the American Museum of Natural History. In this drawing *L* represents the left anterior rhomboid peristomial plate; *R*, the corresponding plate on the right side; *P*, the quadrangular plate on the posterior side of the peristomial slit. The basal plates of the rays are numbered so as to indicate the rays to which they belong. The proximal part of the anterior ray is directed toward the left, the position which it usually occupied when the animal rested on an inclined surface. The peristomial slit divided at its left end at plate *Z*, one branch passing between the two plates marked 2, and the other branch between the two plates marked 1. In a similar manner, the slit divided at its right end at plate *Y*. A duct may have opened near the meeting point of plates *P*, 5, and *X*. *X* is merely one of the interambulacral plates. In the case of the anterior ray, No. 3, several of the lateral covering plates are drawn as though they exposed also the basal extensions of these plates, but the latter details were added from the specimen represented by Fig. 5a, on this plate. *C*, one of the lateral covering plates of the specimen represented in Fig. 5A, on this plate, as seen from below, showing two striae at the base, paral el to the length of the ray; also a lateral view of the same, to show its curvature. *D*, lateral view of a covering plate belonging to the opposite side of the ray.

Fig. 6. Agelacrinus cincinnatiensis, Roemer. *A*, lateral covering plate with diagonally directed basal extension, as seen at the angle between two rays, in specimen No. 13266-1-c, in the American Museum of Natural History. *B*, three lateral covering plates, and a lateral view to indicate the curvature of the latter, from specimen No. 1008 *C*, in the James collection, at Chicago University. *C*, two floor plates, showing a narrow longitudinal groove on each side, from a specimen in the Geological Museum of Ohio State University; also a transverse section of the same. *D*, one of the large plates forming the inner band of the peripheral ring, showing the three short vertical ridges near the base of the inner face; from specimen 13266-1-s, of the American Museum of Nat. Hist.; *E*, the edges of several of these plates, as seen from the interior of the theca, showing the location of these vertical ridges in the spaces left between the lateral edges of the adjacent plates, thus giving rigidity to the inner band of the peripheral ring; from specimen 13266-1-r, in the same museum as the last.

Fig. 7. Streptaster septembrachiatus, Miller and Dyer. *A*, view of central part of oral face of theca, as seen from below, including the substomial chamber and the adjacent parts of the rays. The rays are numbered. There appears to be a deep cavity at the posterior border of the substomial chamber, foward of which, as seen from below, there is a quadrangular plate with broad groove ascending it on the left. In the case of the rays, only the floor plates, as seen from below, are indicated. The peristomial plates, as seen from below, are not sufficiently defined to be represented with accuracy. The anus was located close to the substomial chamber, between rays 5 and 1. A part of the surrounding interambulacral area appears to be preserved. *B*, three floor plates as seen from the side, supporting three vertical palisade like lateral covering plates; also an imaginary view of these three floor plates as seen from the top, with facets for the support of two lateral covering plates on each floor plate.

Fig. 8. Thresherodiscus ramosa, Gen. et. sp. nov. Parts of the proximal portions of rays 3, 4 and 5, drawn so as to indicate the usage of certain terms in the accompanying descriptions. The basal parts of the arms are numbered; *f l* indicates the floor plates in the case of the two primary branches of the anterior ray, No. 3; *b* indicates the small bordering interambulacral plates adjoining the floor plates of the anterior ray and the lateral covering plates of one side of the right ray, No. 4; *ia* indicates the location of the large central interambulacral plates, within the zone of much smaller bordering interambulacral plates; *C*, indicates the two rows of lateral covering plates on one of the branches of the right ray, No. 4. The supernumary covering plates along the median line of the ray, between the lateral covering plates, are also indicated in the drawing, without any effort at accuracy of detail, but are not designated by any letter. Only enough is shown in the drawing to illustrate the usage of the terms here indicated.

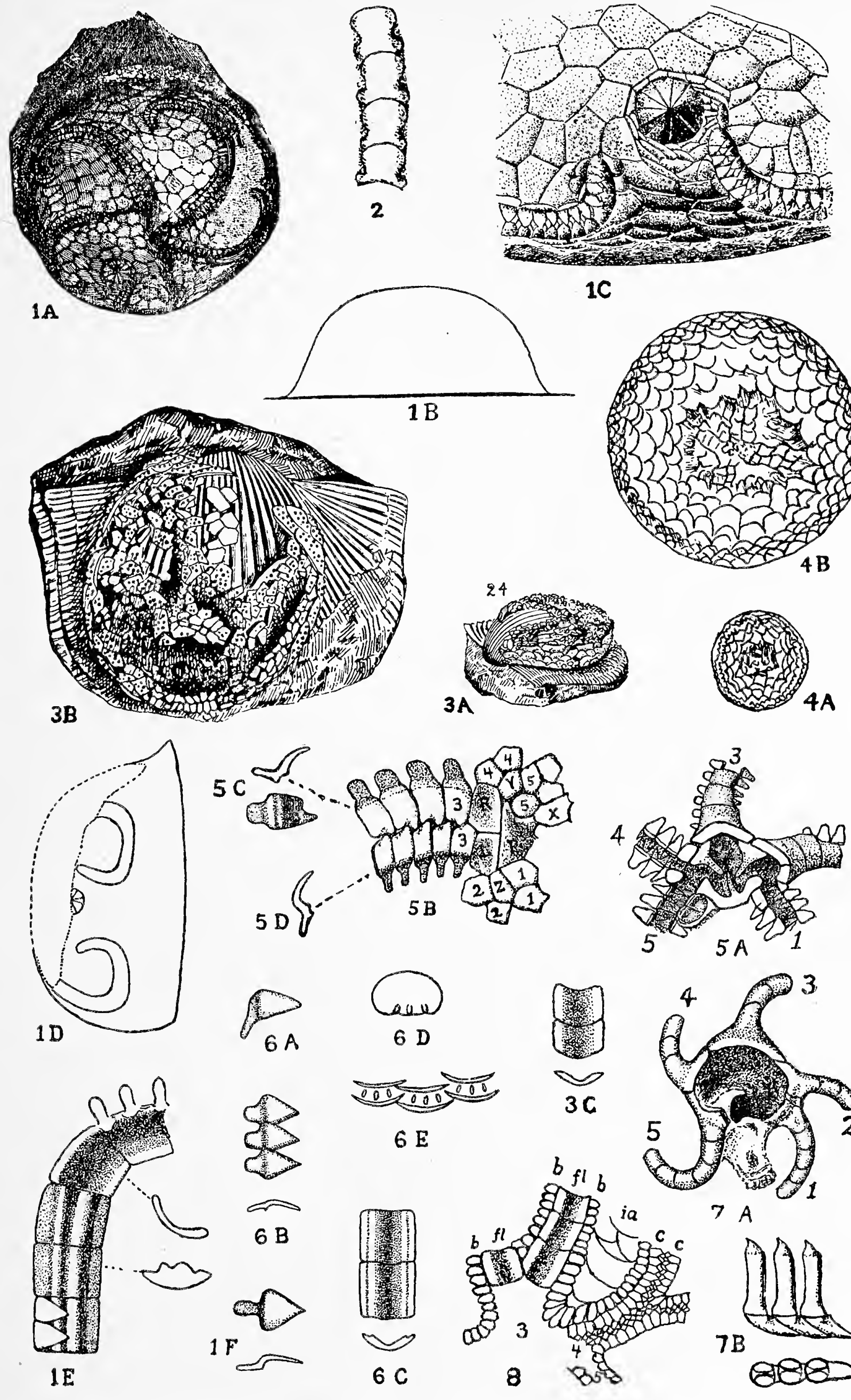

1A
2
1C
1B
4B
24
3B
3A
4A
5C
5B
5D
5A
1D
6A
6D
3C
6E
7A
1E
6B
1F
6C
8
7B
b
fl
ia
c

PLATE II

Fig. 1. Agelacrinus pileus, Hall. The specimen has sagged downward so as to expose the peripheral ring strongly along the upper part of its outline; but, along the lower part of this outline the peripheral ring is almost concealed by the sagging theca. Covering plates with a spinous prolongation on the proximal side. Peristomial plates; and apparently a small opening between plates *P*, 5, and *X* (See diagram 5B on Plate I) are clearly exposed. Several of the plates belonging to the inner band of the peripheral ring are strongly exposed along the upper side of the theca on account of the drag produced by the sagging theca. Specimen No. 13266-1-t, in the American Museum of Natural History, in New York City Enlarged 4 diameters. From Cincinnati, Ohio. Corryville member of Maysville.

Fig. 2. Agelacrinus pileus, Hall. Specimen with surface very minutely pitted, the pits showing in the photograph but not in the engraving. The spinous prolongations along the proximal edges of the covering plates so little in evidence that the tips of the latter, along the median line of the ray, appear like alternating V-shaped terminations. Peristomial plates clearly defined. Contact between plate *X*, and plates *P* and 5 loosened. Anal pyramid apparently consisting of imbricating plates, the tips of the inner plates being exposed. Specimen No. 13268-1-a, in the American Museum of Natural History, in New York City. Enlarged 5 diameters. From Cincinnati, Ohio. Corryville member of Maysville.

Fig. 3. Agelacrinus pileus, Hall. View of lower surface of upper or oral part of theca, showing substomial cavity, with the anterior margin clearly defined. The floor plates of rays 1, 2, and 3, entirely conceal the basal extensions of the covering plates. Specimen No. 13266-1-x, in the American Museum of Natural History, in New York City. Enlarged 4.4 diameters. From Cincinnati, Ohio. Corryville member of Maysville.

Fig. 4. Agelacrinus pileus, Hall View of lower surface of upper or oral part of the theca. This is the speciman figured by Miller and Faber, in the *Journal of the Cincinnati Society of Natural History*, vol. XV, pl. I, fig. 10. The basal extensions of the covering plates are exposed best on rays 1, 2, and 3. The floor plates are seen at the proximal ends of rays 3 and 4; these plates are very thin and the sutures are not well shown. The entire specimen appears far less robust, as seen from the interior, than the specimen represented by figure 3 on this plate. The inner termination of the posterior peristomial plate is well exposed. Specimen No. 8825, Faber Collection, in Walker Museum, at Chicago University. Enlarged 4.5 diameters. From Cincinnati, Ohio. Corryville member of Maysville.

Fig. 5. Lichenocrinus affinis, Miller. Two specimens of the basal attachment disc of some crinoidal body, and the upper surface of the attachment film, as seen after the removal of the plates forming the upper part of this disc. This attachment film is radiately striated. Type, forming specimen No. 8810, in the Faber Collection at Chicago University. Enlarged 4.5 diameters. Probably from upper or Blanchester division of Waynesville, at Lebanon, Ohio.

Fig. 6. Lichenocrinus subaequalis, Foerste. Types, two specimens. Enlarged 3 diameters. From north of Rogers Gap, Kentucky. Rogers Gap member of Cynthiana formation.

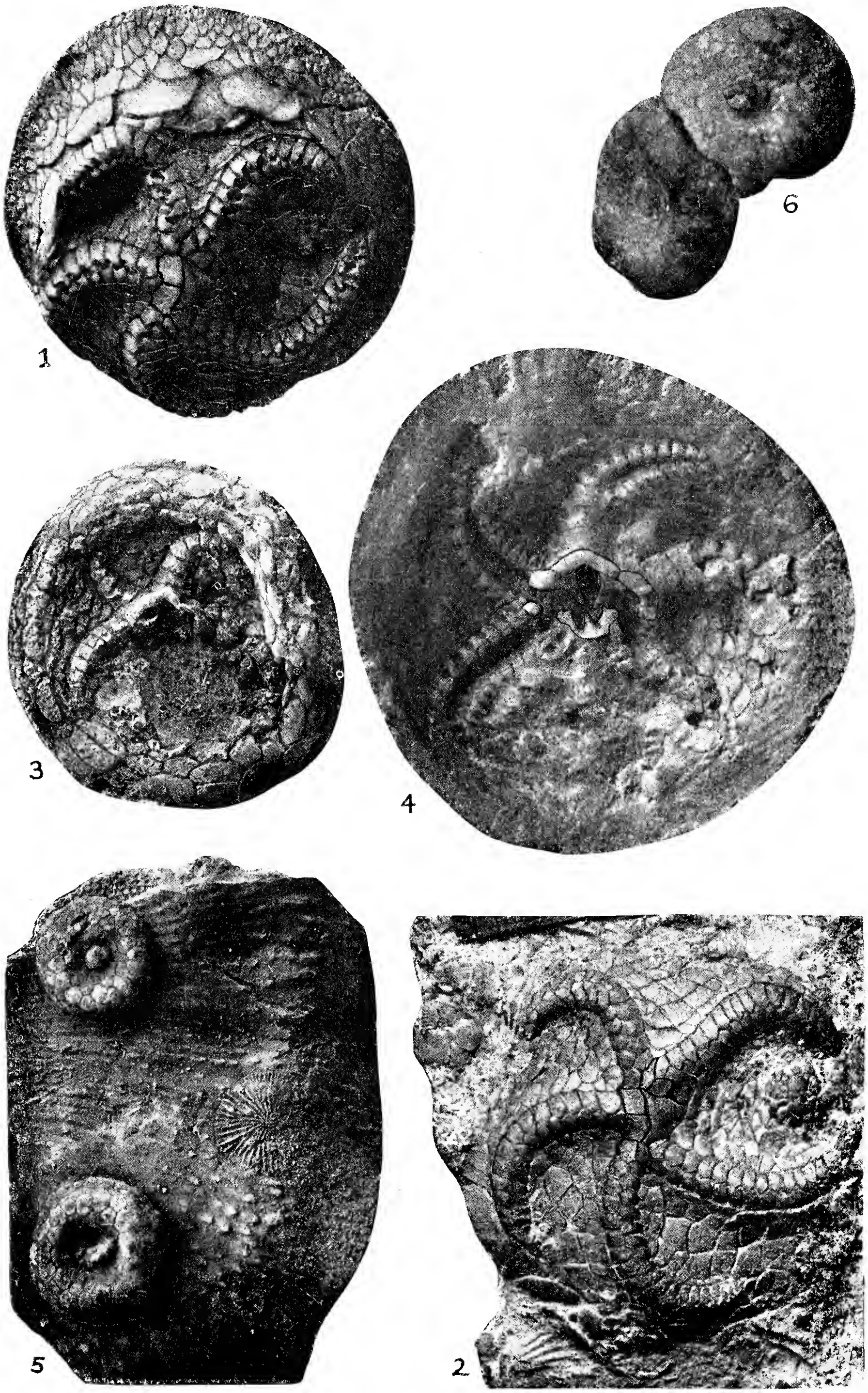

6
1
3
4
5
2

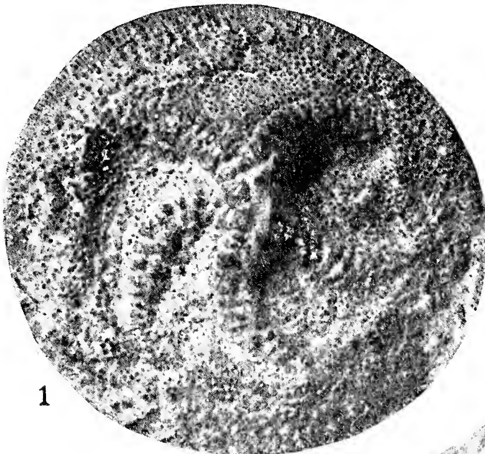
PLATE III

Fig. 1. Agelacrinus vetustus, sp. nov. The granulation probably is due to a thin membrane of Dermatostroma covering the entire animal even before death, but permitting the opening of the ambulacral rays, the peristomial plates, and the anus. From Clays Ferry, 14 miles southeast of Lexington, Kentucky; in the fossiliferous strata between 38 and 69 feet above the massive limestone, near the watering trough on the south side of the Kentucky River. Greendale member of the Cynthiana formation. Magnified 5 diameters.

Fig. 2. Hemicystites carnensis, sp. nov. Two specimens on the same rock fragment, in contact with each other, *A* being located on the right and slightly below *B*, when oriented as in these figures. Both specimens preserve traces of the interambulacral plates in the area on the left of the anterior ray. The covering plates are best preserved in specimen *A*, and this specimen also exposes the nearly horizontal plates belonging to the inner band of the peripheral ring, along the lower margin of the theca. Several hundred yards up the creek from the railroad at Carntown, Kentucky. At the Strophomena vicina horizon, correlated with the strata immediately below the Brannon siliceous limestone, in the Trenton of Central Kentucky. About 20 feet above the level of the Ohio River. Magnified 5 diameters.

Fig. 3. Thresherodiscus ramosa, Gen. et sp. nov. The floor plates are exposed along most parts of rays Nos. 1, 2, and 3. (See text figure of ray system, page V.) Lateral covering plates are seen along the upper side of the left primary ray, on the left side of ray No. 1, on the upper side of ray No. 4, and on the left side of ray No. 5. The central or median covering plates are present on various branches of rays Nos. 4 and 5, but are not distinguishable in the figure. The large central interambulacral plates are surrounded by a series of much smaller interambulacral plates which border upon the rays. From the Kirkfield or Curdsville member of the Trenton, along the railroad at the northeastern edge of Goat Island, northeast of Little Current, the chief village on Manitoulin Island, in Lake Huron. Magnified 5.7 diameters. Specimen No. 8446 in the collections of the Geological Survey of Canada, in the Victoria Memorial Museum, at Ottawa, Canada.

Fig. 4. Agelacrinus faberi, Miller. Resting on Hebertella alveata, Foerste. The granulated surface seen on various plates is regarded as due to a coating of some Dermatostroma. Near the central part of the figure two floor plates are shown at a point indicated by a tiny white arrow. Type, forming No. 8821 in the Faber Collection at Chicago University. Probably from the Whitewater member of the Richmond, immediately above the typical Saluda, at the exposure on the road side half way between Versailles and Osgood, along the road leading northward from the northeastern corner of the town square, at Versailles, Indiana. Magnified 4.5 diameters.



1

2 A

2 B

3

4

PLATE IV

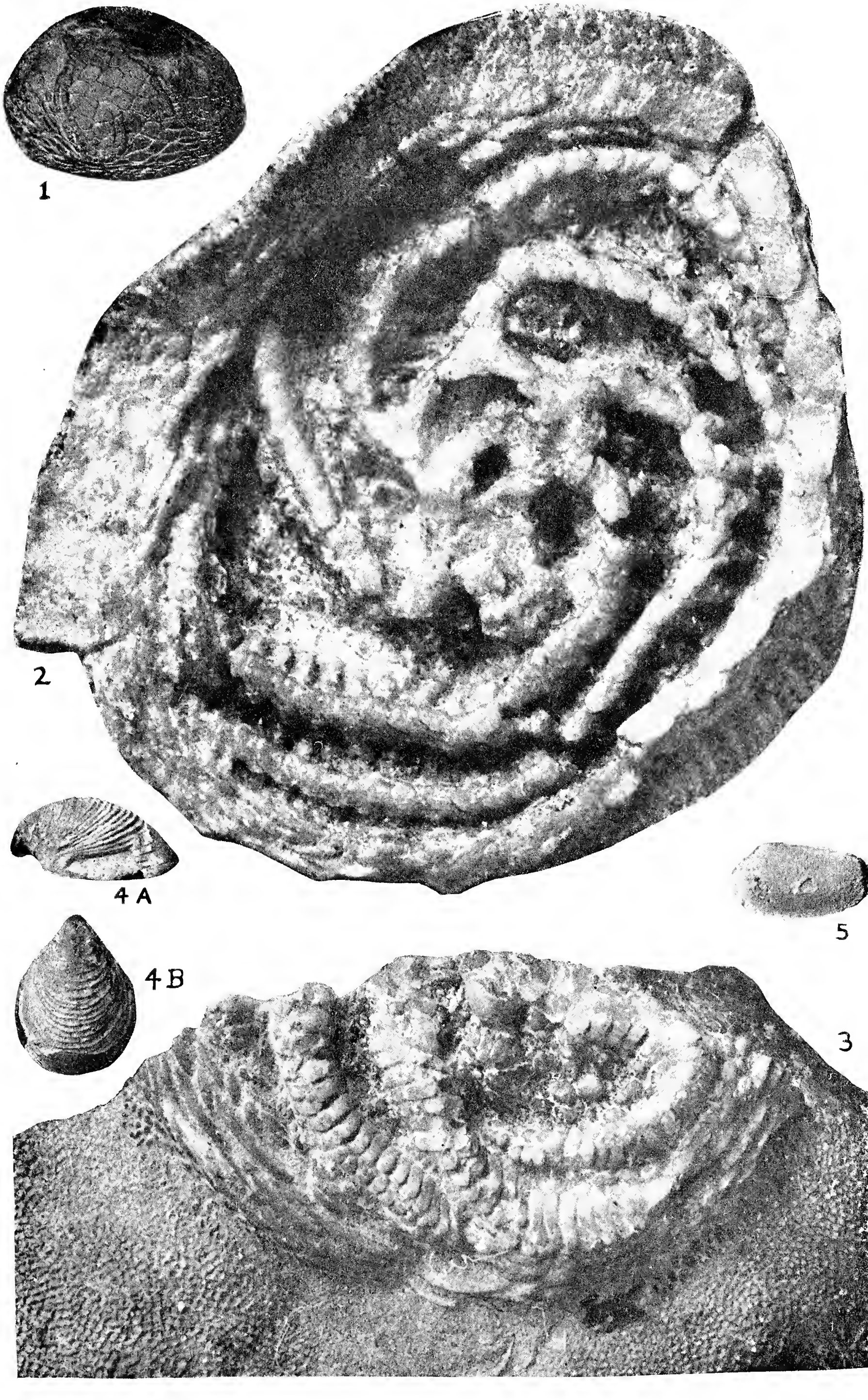
Fig. 1. Agelacrinus holbrooki, James. Showing the interambulacral plates between rays Nos. 1 and 2. Specimen No. 1004, in the James Collection at Chicago University Labelled as coming from near Lebanon, Ohio, and cited by John M. Nickles from the Corryville member of the Maysville formation.

Fig. 2. Streptaster septembrachiatus, Miller and Dyer. Under surface of upper or oral side of theca, showing the substomial chamber with the deep cavity or aperture at its posterior margin, and the inclined surface at the left of this margin. The floor plates are shown along the narrow bases of all the rays, and very much fore-shortened covering plates are seen along the side of the rays. Along the right margin of the figure some of the plates belonging to the inner band of the peripheral ring are nearly horizontal. From the Elkhorn member of the Richmond, six and a half miles west of the courthouse at Dayton, a sixth of a mile north of the Eaton pike, and about the same distance west of the Union road which leads northward to Trotwood, Ohio.

Fig. 3. Streptaster reversata, sp. nov. Fragment showing posterior half of theca, including nearly all of rays 1 and 5, with the intermediate posterior or anal interambulacral area; the latter shows the mosaic of small polygonal interambulacral plates; and the anal pyramid. Small interambulacral plates are shown also between ray No. 1 and the distal half of ray No. 2; also on the left of ray No. 2, as far up as the tip of ray No. 3. The upper edges of the large plates forming the inner band of the peripheral ring are well exposed, but only a part of the marginal plates of this ring are seen at several points. West of tressel 51, about two miles west of Million, in Madison County, Kentucky, west of Richmond. Horizon not definitely known but regarded as middle Eden Magnified 4.4 diameters.

Fig. 4. Vallatotheca manitoulini, Gen. et sp. nov. *A*, Lateral view; *B*, viewed from above. Genotype, differing from the congeneric Stenotheca unguiformis, Ulrich, in its much larger size and the greater curvature of the beak. The concentric markings are not due to transverse folds, but are successive lamellose outgrowths of the shell, striated only on their api al sides. From the Cape Smyth or Waynesville member of the Richmond, at the Clay Cliffs, on the eastern side of Cape Smyth, three miles north of Wekwemikongsing, on the eastern shore of Manitoulin Island. Specimen No. 8448, in the collections of the Geological Survey of Canada, in Victoria Memorial Museum, at Ottawa, Canada.

Fig. 5. Rhytimya kagawongensis, sp. nov. Mesial sulcus faint or obsolete. Concentric lines not more prominent anteriorly. Radiate lines, 7 to 10 in a width of 3 mm. on the posterior parts of the shell, increasing to 12 and more in same width anteriorly; consisting of discrete granules, enlarging in size posteriorly, where 6 may occur in a length of 1 mm. Characterized by its even and comparatively strong convexity, the umbonal ridge being only slightly defined at the beak, merging into the general convexity of the shell. Along the road from Kagawong to Gore Bay, several hundred yards before reaching the margin of the outcrop of the Cataract limestone, about two miles southwest of Kagawong, on Manitoulin Island. Specimen No. 8449, in the collections of the Geological Survey of Canada, in the Victoria Memorial Museum, at Ottawa, Canada.



1

2

4 A

5

4 B

3

PLATE V

Fig. 1. Lepadocystis moorei, Meek. *A*, anterior view, exposing plate 15 and the anterior subvective food groove; also pectinirhombs 14–15, and 10–15. *B*, posterior view, showing pectinirhomb 11–17 on left side, pectinirhomb 12–18 near median line, and anal pyramid on right side of figure. Also right and left posterior subvective food grooves, with all of the distal floor plates dropped off in case of the right ambulacrum, and all but the terminal one of the distal floor plates gone in case of the left ambulacrum, in both cases leaving flattened surfaces, indicating the paths of the ambulacra. *C*, Left side of specimen *A*, broken at the base; with pectinirhombs 1–5, and 11–17; also the left anterior and left posterior branches of the subvective system. *D*, View of specimen *B*, from above, showing the subvective system, with the anterior branch directed toward the top of the figure. Along the lower margin of this figure the position of pectinirhombs 11–17, and 12–18, and location of the anal pyramid are indicated, indistinctly, in the shadows. Specimens No. 9961, in the Faber Collection at Chicago University. Figures *A* and *C* are prepared from the specimen lettered *A*; and figures *B* and *D*, from the specimen lettered *B*. From the Whitewater division of the Richmond, at Richmond, Indiana. Figures *A*, *G*, magnified 5.3 diameters. Figures *C*, *D*, magnified 4.7 diameters.

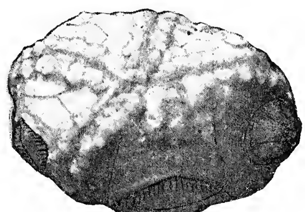
Fig. 2. Brockocystis tecumsethi, Billings. Genotype, and neotype of the species. *A*, View of top or oral end of specimen, but with anterior groove of subvective system directed toward the right. The large cavity on the right indicates the location of that part of the pectinirhomb 10–15 which is found on the nearly hemispherical plate 10. The cavity adjoining the lower left hand margin of the latter, in the figure, is the remainder of the pectinirhomb, with most of the stereom folds weathered out, and is located on plate 15. The cavity just beneath is the upper right hand side of that part of pectinirhomb which is located on plate 15. The longitudinal cavity on the left side of the figure is bordered on the left by the remains of the stereom folds on plate 12. The distal floor plates of all branches of the subvective system, excepting the right posterior branch, are missing and have left flattened areas on the theca. Traces of the hydropore and gonopore apparently present on the left of the center of the subvective system. *B*, posterior view; the large cavity locates pectinirhomb 12–18. The absence of the pectinirhomb on plates 11–17, immediately on the left of this cavity, is well shown. Pectinirhomb 1–5 is seen at the lower left hand margin of the figure. The anal area lies in the most deeply indented part of the outline on the right hand margin of the figure. *C*, View of right anterior side of specimen. The large cavity on the left side of the figure locates the anal area. Pectinirhombs 14–15, and 10–15 clearly indicated; also the flattened surfaces on the theca left by the dropping off of the floor plates from the distal ends of the branches of the subvective system. From the top of the Cataract limestone, on the road from Gore Bay to Kagawong, at the first wet weather stream crossing east of Ice Lake, on Manitoulin Island, in Lake Huron, *A*, Magnified 4.7 diameters; *B*, *C*, magnified 3 diameters. Specimen No. 847 in the collections of the Geological Survey of Canada, in the Victoria Memorial Museum, at Ottawa, Canada.

1 A

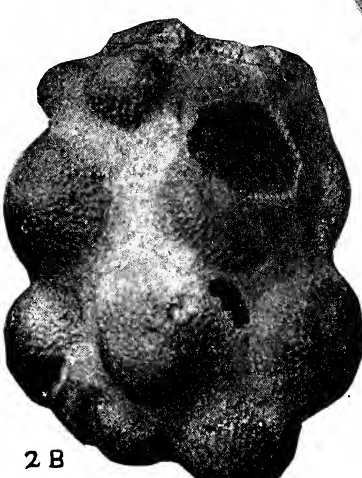
2 A

1 B

1 C



1 D



2 B

2 C

Fig. 1. Agelacrinus *austini*, Foerste. *A*, specimen showing peripheral ring, with outer zone of small marginal plates, and inner band of larger plates. The anal pyramid is on the right, a short distance above the horizontal diameter. Ray 5 is directed upward and toward the right. Ray 4 is turned toward the left. The terminal part of ray 3 is well preserved. The long median or central covering plates are well shown in the specimen but can not be distinguished in the figure. *B*, lower side of upper part of the theca, showing the substomial chamber. The anterior outline, formed by the modified proximal floor plates of rays 2, 3 and 4, is well preserved. The outer ends of the proximal floor plates of rays 1 and 5 are in position, but the inner ends, toward the median line of the specimen, have been swung forward, partly closing the substomial ravity, evidently owing to displacement after death. The floor plates of rays 2 and 3, and a part of those of ray 1, are well preserved. They consist of a single series in the case of each ray, and no glimpse of the basal extensions of the lateral covering plates may be seen. *C*, one of three specimens resting upon the flattened surface of a bryozoan which had been very much worn before the attachment of the specimens. Anal area on the left. The curvature of the rays is less than in fig. 1*a*. Interambulacral plates more numerous in the distal part of the posterior area than in any of the other interambulacral areas. All figures magnified 4.2 diameters. Specimens in the collection of Dr. G. M. Austin; from the Drepanella richardsoni horizon, at the top of the Whitewater member of the Richmond, on Dutch creek, south of the Oakland pike, four and a half miles northwest of Wilmington, Ohio.

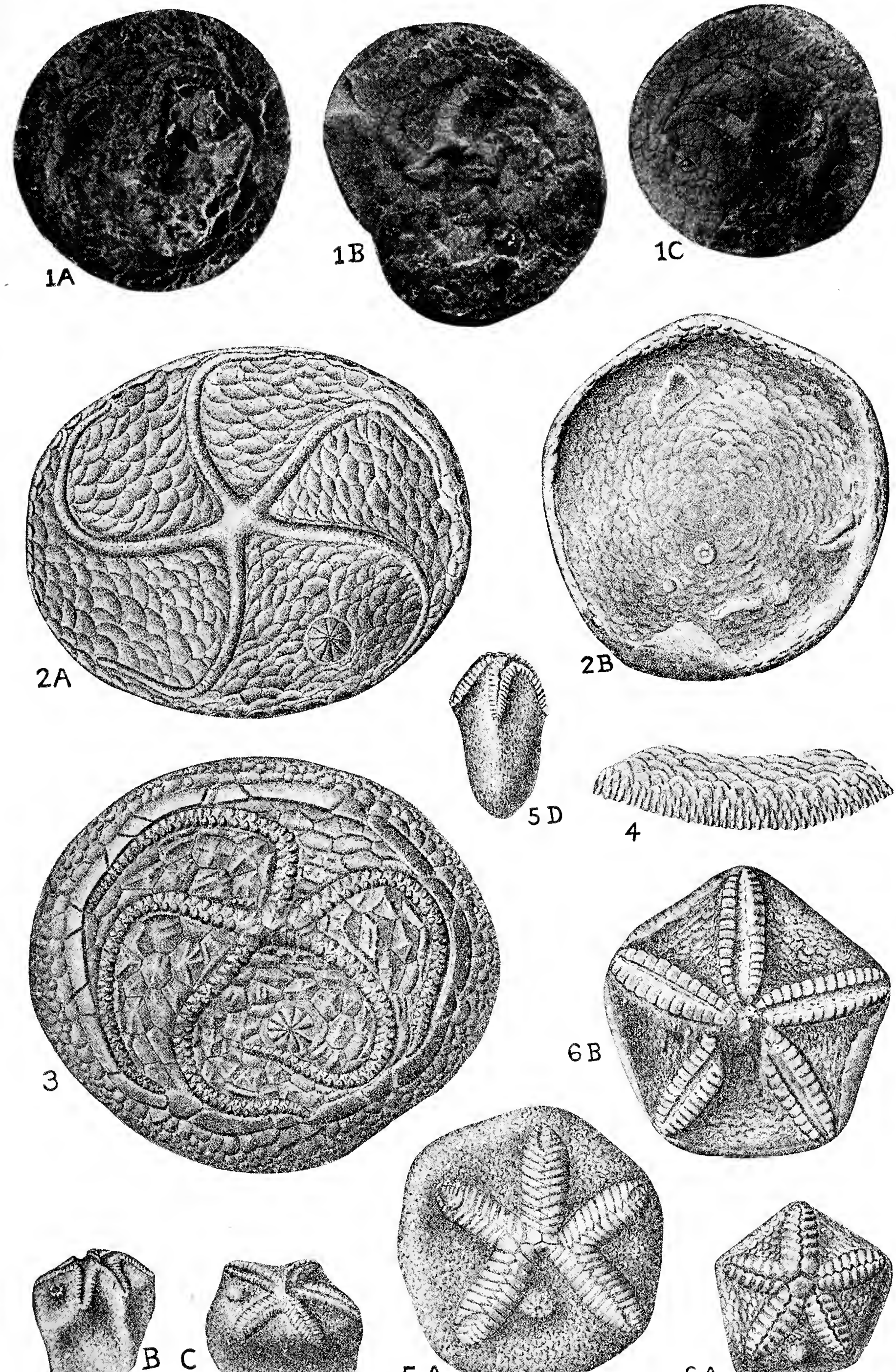
Fig. 2. Lepidodiscus alleganius, Clarke. *A*, oral aspect of a mature individual, showing the extremely narrow, undulating, whiplash rays, all solar; the small cover plates; the anal pyramid composed of 10 triangular plates; and the absence of specially differentiated marginal plates. Magnified 1.5 diameters. Chemung sandstone. Loose at Alfred, New York. *B*, Aboral aspect of a large individual, showing the depressed surface with imbricating plates directed centrifugally and the projecting margin of coarser plates. Natural size. Chemung sandstone. Loose at Belvidere, New York. Figures copied from Bull. 49, N. Y. State Museum, 1901, pl. 10, figs. 4, 2. Plastotypes Nos. 4285-4 and 2 respectively, in the New York State Museum, at Albany, N. Y.

Fig. 3. Agelacrinites hamiltonensis, Vanuxem. Drawing made from guttapercha replica of original, showing form and direction of rays, the large submarginal and small marginal plates, the sculptured surface of the interambulacral plates, and the anal pyramid. Magnified 2 diameters. Hamilton beds. West Hamilton, Madison county, New York. Part of figure 6, on pl. 10 of Bull. 49, N. Y. State Museum, 1901. Plastotype No. 4000-1, New York State Museum.

Fig. 4. Streptaster vorticellatus, Hall. A portion of the peripheral ring of the type, showing the relative size and arrangement of the plates. Magnified 5 diameters. Maysville formation, Cincinnati, Ohio. Type, No. 1192, in the American Museum of Natural History, in New York City. Copy of fig. 12 on pl. 6, of the 24th Annual Report of the N. Y. State Museum, 1872.

Fig. 5. Cystaster granulatus, Hall. *A*, view of the summit of a specimen, enlarged 4 diameters, showing the covering plates of the rays and the anal pyramid. *B*, lateral view of a specimen, with the covering plates of the rays missing; only lower range of plates of anal pyramid present, lower margin shows cicatrix of attachment to some foreign body. *C*, oblique summit view of another individual, with covering plates present only on the two nearer rays. *B* and *C*, enlarged 2.5 diameters. *D*, lateral view of a specimen with a more elongate body, pointed below, showing no evidence of having been attached; covering plates absent. Enlarged 3 diameters. The originals of figures *B*, *C*, and *D* are numbered 40 in the Dyer collection, at Harvard University. The original of fig. A should be in the same collection but was not noticed by me. Fairmount member of the Maysville formation, at Cincinnati, Ohio. Copied from figs. 1, 2, 3, 4, on pl. 6, in the 24th Ann. Rept. N. Y. State Museum.

Fig. 6. Hemicystites stellatus, Hall. *A*, a small individual, enlarged 6 diameters. Rays with covering plates, about 7 or 8 in each range. With distinct imbricating plates and anal pyramid. On Rafinesquina alternata. Type, No. 1191-1, in the American Museum of Natural History, in New York City. *B*, a summit view of a larger individual, enlarged 4 diameters. Covering plates missing. Interambulacral plates in the upper left-hand area, distinctly imbricating. Maysville formation. No. 1193 in Dyer collection at Harvard University.


1A
1B
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